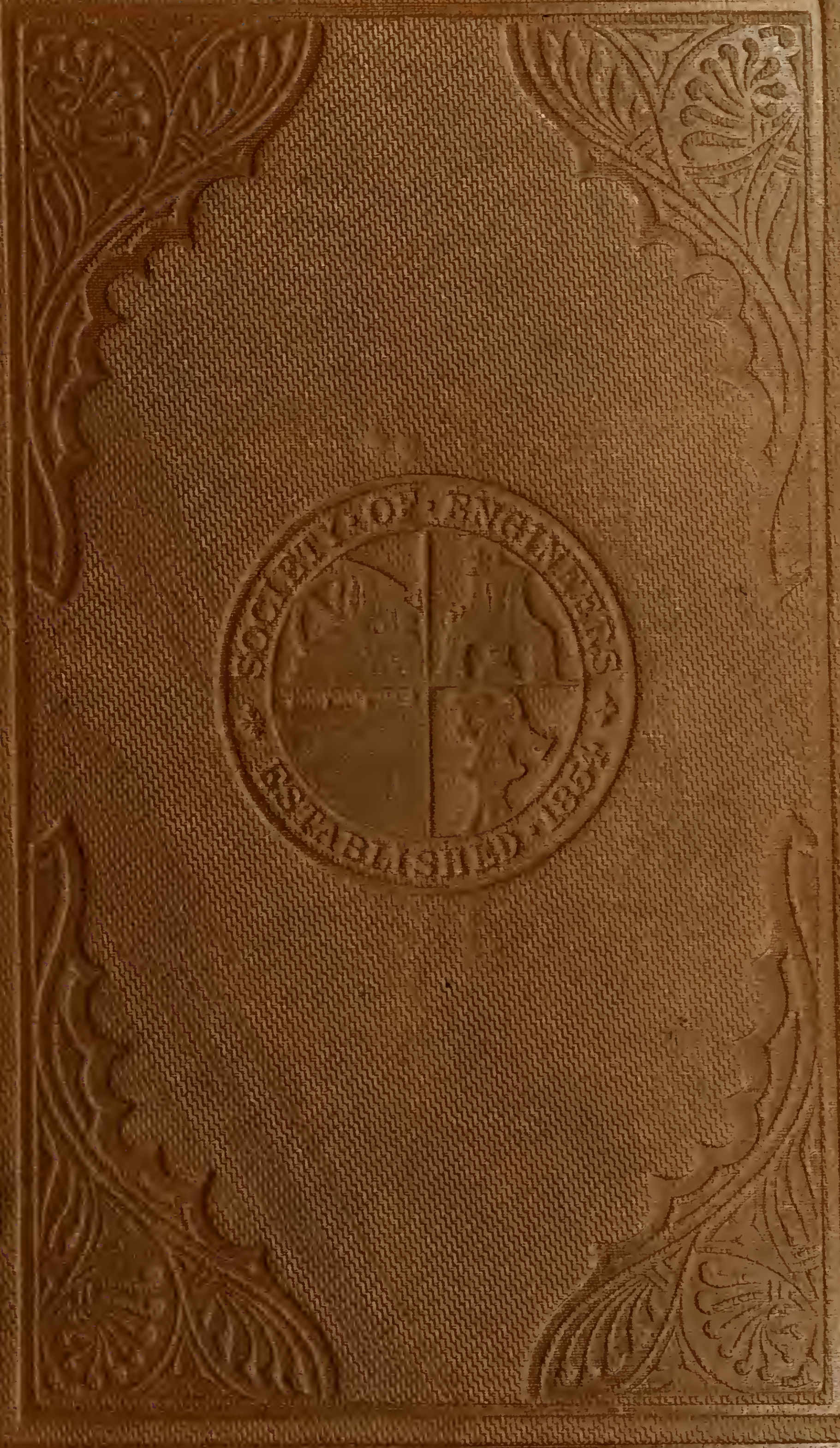
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SOCIETY OF ENGINEERS

ESTABLISHED MAY 1854

Journal and

TRANSACTIONS FOR 1897

AND

GENERAL INDEX, 1857 TO 1897

EDITED BY

G. A. PRYCE CUXSON

SECRETARY

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For any papers that may be considered sufficiently meritorious the Council may at discretion award one or other of the following Premiums, viz.:—

1. The President's Premium, given annually by the President, and consisting of a Gold Medal of the value of Five Guineas.
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By the Rules of the Society, Members of Council are debarred from receiving Premiums.

PREMIUMS FOR 1897.

At a Meeting of the Society, held on February 7, 1898, the following Premiums of Books, &c., were presented, viz.:—

The President's Gold Medal to:

RICHARD FUGE GRANTHAM, for his paper on Sea Defences.

The Bessemer Premium to:

PHILIP MICHAEL FARADAY, for his paper on The Rating of Engineering Undertakings.

The Rawlinson Premium to:

REGINALD EMPSON MIDDLETON, for his paper on The Pollution of Water, and its Correction.

A Society's Premium to:

Professor HERBERT WILLIAMS UMNEY, for his paper on The Compression of Air by the Direct Action of Water.

A Society's Premium to:

JAMES CROLL, for his paper on Filter Presses for Sewage Sludge.

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ESTABLISHED MAY 1854.

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1898

TRANSACTIONS, &c.

February 1*st*, 1897.

INAUGURAL ADDRESS.

By GEORGE MAXWELL LAWFORD, President.

In addressing you for the first time as President of this Society, I have to express my thanks for the honour you have conferred upon me in electing me to that important position, and at the same time I have to ask your indulgence for my own shortcomings, as I am, comparatively speaking, one of the younger members of the Society.

Through deaths and resignations I have attained to the chair of office some years earlier than would have been the case in the ordinary sequence of events; however, I trust to atone for my inexperience by giving every possible care and attention, not only to my duties as President, but also to furthering in every way the interest of the Society of Engineers.

Our financial position is fortunately most satisfactory, and we have a considerable balance on deposit with our bankers, while the continued use of the theatre of the Royal United Service Institution should certainly not be an unimportant factor in the attendance of members and visitors at our meetings.

During the past year our roll of membership has remained stationary, the losses from all causes amounting to 23, while the number of new members elected during that period is also 23, our total membership of all classes being now 488. I would therefore ask you all to make a special effort by inducing new members to join our Society during the ensuing year, to cause our curve of membership once more to revert to the up grade.

The papers read and discussed during the past twelve months have fully maintained the average both in merit and usefulness, and will appear in full in our 'Transactions.' The Council have made the following awards to the authors of four of the papers, namely:—

The President's Gold Medal to Mr. George Thudichum for his paper on "The Ultimate Purification of Sewage."

The Bessemer premium to Mr. D. B. Butler for his paper on "The Effect of Admixtures of Kentish Ragstone, &c., upon Portland Cement."

The Rawlinson premium to Mr. W. G. Wales for his paper on "Discharging and Elevating Grain."

A Society's premium to Mr. M. A. Pollard-Urquhart for his paper on "Examples of Railway Bridges for branch lines."

The remaining papers were by Mr. T. H. Brigg, on "The Mechanics of Horse Haulage"; by Mr. Arthur Rigg, Past-President, on "Hydraulic Rotative Engines"; and by Mr. Percy Griffith, on "The Water-supply of Small Towns and Rural Districts." The last-mentioned paper was ineligible for a premium in consequence of its author being a member of council.

The customary visits of the Society during the summer vacation to works of engineering interest took place as follows:—In June, to the Surrey Commercial Docks, Rotherhithe, where extensive additions to the dock and quay accommodation, and a new deep-water entrance lock are in course of construction to meet the requirements of the large steamers engaged in the timber and grain trades now frequenting the Port of London. The hydraulic machinery for discharging and elevating grain was also inspected.

In July, to the Rugby and Byfield section of the Manchester, Sheffield and Lincolnshire Railway Company's extension to London, the most important works on this length comprising the several crossings of the Oxford Canal and Leam Valley, and the Catesby Tunnel, which is 3000 yards in length.

In October, to the very interesting works of the Westinghouse Brake Company at King's Cross, where the mechanism and working of this most important and indispensable adjunct to the railway systems of both hemispheres was thoroughly explained; subsequently proceeding to the Somers Town Goods Depôt of the Midland Railway Company, which constitutes a striking illustration of the principles of direct connection between the goods shed and the main line.

The attendances of members on the occasions of these visits showed a marked falling off, and I would take this opportunity of reminding the younger members particularly of the great advantages in the way of instituting comparisons which these visits afford, and further, that such small musters are a very poor compliment to those gentlemen in charge of the different works, who kindly place their time and services at our disposal.

We cannot but regret the unavoidable absence from England of my immediate predecessor, Mr. Herbert Cox, during the greater part of his year of office; but as every picture has its reverse, we can, and do sincerely hope, that our loss was his gain, and that now, though from one point of view he is on the shelf, the Council will still have the benefit of his presence and assistance, whenever possible.

Nearly twenty years ago, when I was a student at the Crystal Palace Engineering School, Sir Douglas Fox, addressing us at the close of the session, stated that the profession of a civil engineer yielded precedence only to the Christian ministry and the medical profession. In joining issue with Sir Douglas on the second point, and with due deference to his then expressed opinion, I now contend that we should not only be placed on an equality with our medical confrères, but, with submission to their acknowledged position, I claim priority, as by our provision of pure water and efficient drainage, we prevent as far as possible, the zymotic diseases, which they would otherwise be called in to alleviate. In support of my contention, may I quote the words which have no doubt occurred to all of you, "Prevention is better than cure."

We have only to look at the steady reduction in the general death rates during the last fifty years, and the comparative freedom from zymotic diseases which we now enjoy, to realise what sanitary science has done for our country. The passing of the Public Health Act of 1875, followed by the different Acts for the prevention of river pollution, has undoubtedly given an impetus to the study of hygiene, which has resulted in the attention of many members of our profession being applied to the hygienic requirements of urban and rural communities.

It is with special reference to the provision of pure water and efficient drainage, that I propose addressing you this evening, and although two of my predecessors in this chair have dealt very exhaustively with the question of water-supply, in their presidential addresses (I allude to Mr. Valon and Mr. Peirce) much remains to be said as to its purification.

Of the many additions to science brought into prominence during the record reign of our beloved Queen, biology most assuredly stands pre-eminent. The discovery of the infinitely small organisms with which we are surrounded, their life-functions, classification, distribution, and finally, the determination of the organic ferments, marks an epoch unequalled in the annals of science, and when, in three short years, historians compile the death-roll of the nineteenth century, foremost on the list of those illustrious men of science who have passed away from us, leaving behind as their record works of inestimable benefit to mankind, will surely be found the name of Pasteur.

The important results obtained by the biological analysis of water have naturally caused increased attention to be given to filtration and to bacterial purification. This increased attention is, I need scarcely say, more necessary in the cases of towns taking their supply from sources liable to pollution (such as the Thames and Severn) than in the cases of those towns supplied either by deep wells, or by lakes from which the supply has been conclusively proved to be beyond question. Speaking of lake supplies, I should sub-divide them into two classes: the natural, instanced by Loch Katrine and Thirlmere, supplying Glasgow and Manchester respectively; and the artificial, instanced by Lake Vyrnwy, supplying Liverpool, and the Elan Valley scheme, which is eventually to supply Birmingham.

It may perhaps, be of interest if I give you a few brief details concerning the water-supplies of the four towns I have just mentioned.

In 1855, the Glasgow municipality bought out its water companies, and in the following year commenced the works, which now give them a constant and abundant supply of pure water from Loch Katrine. These works, coupled with the available supply from the then existing companies' works, gave the city a daily supply of 50 million gallons for a population of 850,000, or roundly 60 gallons per head. Ten years ago additional works were commenced, and are now approaching completion, which will more than double the existing supply, and will provide amply for four times the present population. It is a fact worthy of special note that these additional works will involve no increase in the rates, being paid for entirely out of the profits accruing to the municipality from the administration of the water trust.

Manchester was even earlier in the field than Glasgow, and bought out its water companies in 1847, then going for an increased supply to the valley of Longdendale. The present supply from these works is 25 million gallons daily to a population of 1,000,000, but in spite of the ample provision of storage, viz. 150 days' supply in the reservoirs adjoining the city, and another 100 days' supply in the collecting and storage reservoirs at Longdendale, the corporation decided to put water famines beyond the pale of possibility, and in 1885 commenced that grand series of works which brings to their doors the waters of Thirlmere. These works, nearly one hundred miles in length, will ultimately yield 50 million gallons per day, while when all the accessory works are completed there will be storage capacity sufficient to last through five months of absolute drought.

The growth of the city has been carefully studied, and provision has now been made to give an adequate constant supply to a population two and a half times as great as now exists.

Liverpool was only four years later than its sister town in buying up its water companies, following this act, in 1881, by capturing the waters of Lake Vyrnwy and bringing them into Liverpool by an aqueduct 77 miles in length. The present population is 800,000, while the daily supply is 40 gallons per head. If the population was doubled, there would still be an available daily supply of 35 gallons per head, or a total yield of over 40 million gallons per day.

Birmingham, undoubtedly wise in its own generation, acquired its water companies in 1876, since which time the daily requirements have been more than doubled, rising from eight million gallons to 17 million in 1891. The present consumption is at the rate of about 26 gallons per head per day for a population of nearly 700,000, but this relatively low consumption is due in a very great measure to the efficient arrangements made for the checking of waste.

Birmingham, prudently looking ahead, commenced in 1892 the Elan Valley scheme, which will impound the waters of that river in a chain or a series of artificial lakes, and convey them to Birmingham by 80 miles of aqueduct. The additional supply which will be ultimately available amounts to 60 million gallons daily, while the future population for which provision has been made is three times the present, or in round figures 2,000,000.

Apart from supplying a vital necessity, these four great works will worthily perpetuate the names of some of our most prominent engineers, and especially that of the late Mr. Bateman, the originator of the system of lake supplies.

The contrast between these great municipal undertakings and London is most significant. While every town of importance in the United Kingdom owns its waterworks and, in addition, is making provision for fresh sources of supply, far removed from large inhabited areas, London still continues to be dependent on monopolist companies, drawing by far the greater part of their supplies from the crowded and polluted valleys of the Thames and Lea, and relying entirely for the purity of those supplies on the beneficent organisms that occupy their filters. The total area of the present London filters exceeds 100 acres, and as 88 per cent. of the entire daily supply, which approximates 190,000,000 gallons, has to pass through them, the importance of biological analysis is fully manifested. Although it is fashionable to decry anything "made in Germany," the wisdom of the Government of that country in compelling every waterworks undertaking to equip and maintain a biological laboratory, and to record the results therein obtained, is a striking recognition of the importance of the subject, and an example which we should do well to follow.

I may perhaps be pardoned for adapting a well-worn saying at the present juncture, "Who shall decide when experts disagree?" This appears to me to be singularly appropriate when, on the one hand, we have direct differences of opinion between the most eminent contemporary scientists of the day as to the quality of the metropolitan water supply, and, on the other hand, between distinguished engineers as to the ultimate sources of that supply.

The recent failures of one of the largest of the London companies to maintain its supply, in the first instance, during the severe frost in 1895, and again during the prolonged drought of last summer, may be cited as an argument that the London supply should be managed in the interests of the consumers, and not in those of shareholders, and there can be little doubt that this will be the ultimate issue.

Whether this takes the form of municipalisation, of an amalgamation of the present companies, or of the formation of a water trust, the control of the undertaking (and this I cannot say too strongly) should be in the hands of a body from which party and political feeling is entirely excluded.

During the past summer, when in Switzerland, the opportunity was given me, through the kindness of Dr. Lunge, Professor of Chemistry at the University of Zurich, of inspecting the waterworks of that town, and a short description of them may be of interest, as affording a most striking example of the definition of civil engineering, namely, "the conversion of the great sources of power in nature to the use and service of man."

The River Limmat, on the banks of which Zurich is situated, is utilised to draw the water from the lake to the filters; to raise it thence to the distributing reservoirs; to generate high-pressure hydraulic power; to generate power for wire rope transmission; and to generate the whole of the electricity used in the town for the purposes of lighting, motors and traction.

The river, which is partly canalised for the purposes of the works, is the natural outlet for the Lake of Zurich, the average daily discharge being 1800 million gallons, with an available fall varying from 5 feet in summer to 10 feet in winter. The conversion of this flow into power is effected by twelve turbines, aggregating 1200 horse-power; each turbine is connected to a shaft 330 feet in length, to which two auxiliary steam engines are also connected. Each or any turbine or engine can be used as may be found necessary. The whole of the machinery is under one roof, the building being 375 feet in length by 75 feet in width, lighted by electricity, and presenting a magnificent spectacle, even to non-technical minds.

So far as the waterworks are concerned, the water is taken from the lake at a depth of 46 feet from the surface and 10 feet above the bottom, at which point it was found to be the purest; it then flows by gravitation through a 36-inch main to the filters. After filtration it is pumped by means of Girard pumps actuated by the turbines to three covered distributing service-reservoirs, each commanding a zone of different pressure.

The filters are ten in number, with an average filtration area of 800 square yards per filter, and are all covered with arched concrete roofs. The filtering medium consists of a layer of fine washed sand 2 feet 9 inches in depth, resting on a layer of 15 inches of coarse sand and gravel surrounding the underdrains. The sand used is taken from the lake bed and is cleaned by means of a sand-washer worked by a hydraulic motor. The depth of water when the filters are working is kept at 8 feet, while the water-level in the service reservoirs is shown in the engine-house by electric indicators.

The reservoirs only contain about two hours' supply, which of course strikes us as unusually small; but, as Dr. Lunge observed, the lake is the reservoir, and there is therefore no necessity to construct large storage reservoirs; while, in the event of fire or any similar emergency, river water can be pumped direct into the mains. I am indebted to Dr. Lunge and the resident engineer, Herr Peters, not only for a most interesting visit, but for the exhaustive information so kindly volunteered.

Nature has not afforded us, in Great Britain, the opportunity of utilising water power in the effective way it is used in Switzerland, and as a perfect example of successful and economical municipal enterprise, the Zurich waterworks are unparalleled in the records of hydraulic engineering.

In entering upon the second portion of my address, namely, efficient drainage, the subject can, if used, like steam, expansively, be made to fill an entire volume. I, however, intend dealing with drainage only in its relation to water supply, that is to say, the effective removal and eventual disposal of that water supply which, after pollution and fouling, has, under the name of sewage, to be dealt with and again purified.

This removal and disposal I propose treating under the three headings of the house, the sewer and the outfall.

The first of these requires very little comment; the very stringent by-laws relating to house-drainage, which are now universally adopted and enforced by all urban authorities and a daily increasing number of rural authorities, are in themselves a sufficient safeguard in the cases of new buildings. In the cases of existing buildings, intending householders have only to avail themselves of the numerous associations, or to apply to those engineers who make a special practice of sanitary science, in order to protect themselves against the evils arising from defective drainage.

The second heading, that of the sewer, is one which opens up a very wide range, as it includes the questions of combined and separate drainage, gravitation, interception, pumping, ventilation, flushing and, last, but by no means least, construction. I do not propose attempting to enter at length into each of these questions, but there are certain points involving matters of considerable magnitude to which I would draw brief attention.

The battle between the advocates of the combined system, i.e. that which provides for the inclusion of storm-water in the sewers, and the separate system which, as it name implies, deals with sewage only, and a certain unavoidable minimum of rainfall, has been fought out on many a field. The first involves sewers large enough to deal with July thunderstorms, while for the greater part of the year there is only a trickle of foul matter flowing through at a velocity which cannot possibly keep the sewers self-cleansing. The second involves a dual system of pipes or conduits, one for sewage *per se*, and one for storm-water.

Local surroundings and circumstances have invariably to be taken into account, but, where a town is being sewered for the first time, or its sewerage system is being reconstructed, from a hygienic point of view the advantages of the separate system unquestionably outweigh those of the combined. In cases where the contents of the sewers have to be lifted or pumped, the balance in favour of the separate system becomes more marked, as those cases are very few and far between in which a natural outlet cannot be found for storm-water. At the same time there is one very strong argument in favour of the combined system, at all events in our cities and large towns. In paved streets where traffic is fairly heavy, the first shower of rain falling on a surface more or less impervious washes into the sewers a mixture of detritus and horse droppings, which requires quite as much treatment and purification as domestic sewage. In the case of our great metropolis, situated on a free-flowing tidal river, and with sewers well provided with storm-overflows, this is of course not so noticeable as in the many cases of towns on the banks of rivers and streams from which water is abstracted for dietetical purposes.

The point is one which has frequently escaped attention in the past, although now it is fully recognised and met by our municipal engineers, who constitute a very important section in our profession.

The three questions of gravitation, interception and pumping, are dependent entirely on geographical conditions. The broad principle of interception, i.e. that of making as much of the sewage as possible gravitate to its ultimate destination, only leaving such low-lying areas to be pumped as cannot possibly be dealt with otherwise, is one that cannot be too fully recognised. Every gallon of sewage that has to be pumped represents an annual, if infinitesimal, charge to the community, and every gallon that can gravitate is therefore a saving to the ratepayer's pocket.

Sectional pumping, as applied to raising sewage, has made very rapid progress during recent years, and is a remarkable illustration of the successful application of compressed air to this purpose. Hydraulic power has, it is true, been applied in a similar way, but the few examples, in this country at all events, have not been sufficiently successful to warrant the belief that it will supersede its more economical and equally efficient rival.

Sewer ventilation is again a very controversial subject, but without going into such questions as to whether gratings at road level are better than high shafts, or whether a combination of both is better than either, we cannot but feel that the results of the investigations of Mr. Parry Laws and Dr. Andrewes, firstly on sewer air, and secondly on the micro-organisms in sewage, constitute a very important addition to our technical literature.

These investigations were made with the air and sewage of the London sewers, and Mr. Parry Laws' conclusions are "that the micro-organisms in sewer-air are related to the micro-organisms in the atmosphere outside, and not to the organisms of sewage"; and "that the principal, if not the only, source of micro-organisms in sewer-air is the fresh air gaining access to the sewer by means of the ventilating openings."

Another important result was to show that the putrefaction of organic matters in a sewer does not, contrary to the generally received opinion, disseminate microbes in the air immediately above the sewage.

A series of special investigations were undertaken with a view to ascertaining the effect of the organisms in flowing sewage upon the typhoid bacillus, and the experiments showed that sewage is an unfavourable medium for the growth and continued existence of that bacillus.

It is of course impossible to argue from conclusions such as these that sewer air is harmless, but the subject opens a very wide field for research, and as it is not only of special interest to those of us who are engaged in carrying out hygienic works, but to the general public for whose health and well-being we are so largely responsible, it is earnestly to be hoped that some of the scientific bodies who have funds available for research work, will take up the question and throw additional light on a subject still in its infancy.

The construction of sewers and the works accessory thereto, varying in size from the 11 feet diameter London main sewers to the 6-inch pipe of a village, can only be touched on lightly. The exclusion of subsoil water from sewers is, however, now fully recognised, and in water-logged districts cast-iron pipes with turned and bored joints are being largely used for sewers varying from 6 inches up to 5 feet in diameter. These pipes can be laid and jointed in or under water, and I may mention that in one of the last towns drained in the Thames Valley, not only the sewers, 8 miles in length, but the manholes and house connections were all made of this material, with the result that subsoil water has been practically excluded from the sewerage system.

I cannot help thinking that if, in dealing with works of sewerage and sewage disposal, the Local Government Board was to imitate the example of the Board of Trade, and follow up the usual inquiry and sanctioning of the schemes submitted with an official inspection on completion, the result would be beneficial in a marked degree, not only to the engineers responsible for those works, but to the ratepayers who have to pay for them.

The third and final heading, the outfall, opens up the great problem of sewage disposal. Papers innumerable have been read on this subject before scientific societies, and many more will certainly be read in the future, as it is not only common ground on which engineer, chemist and biologist meet, but one which is never-failing in producing interesting and keen discussions.

I do not intend to weary you with a recapitulation of the many processes for purifying sewage which have been put forward from time to time; some of these (the great majority, indeed) have had but a very ephemeral existence; others have dragged on for a year or two, kept alive by industrious and persistent advertising. The advocates for chemical treatment will tell you that sewage farming is a failure, to which the irrigationist replies after the manner of the historic dispute between the pot and kettle. Certainly much may be said on both sides, while a harmonious combination of the two has not infrequently produced excellent results. Artificial filtration of sewage effluents has been much in evidence lately, thus making the battle triangular, while the biological treatment, not only of effluents, but of crude sewage, is also claiming our attention.

Sewage, like the poor, is always with us, but there is absolutely no reason why it should be added to the list of the unemployed, and I venture to predict that the well-known opinion of our honorary member, Sir Robert Rawlinson, "Put back on the land what you have taken from it," will be the key-note to future works of sewage disposal. The investigations of the chemist and biologist have assisted the work of the engineer to such an extent that we now seem to be within measurable distance of the time when sewage, after undergoing a purely natural treatment, can be applied to land in the condition most suited for its assimilation by plant life. In other words, the complex organic matters in water-carried sewage can be converted by natural agencies into the inorganic elements which support and nourish vegetation, thereby completing the great cycle of nature.

That this conversion, taking place both in the soil and in artificial filters, is due to the fermentative action of certain definite micro-organisms, is now no longer a theory, but a fact universally admitted, and the term "mineralisation" has been given to that special process of transformation, by which inert organic products, whether animal or vegetable, become "mineralised," or broken down into inorganic substances.

The organisms by which this change is brought about are inherent in sewage, and if afforded the requisite conditions, will speedily convert the organic solids into a liquid, which, of course, contains ammonia, both free and albuminoid, and nitrites. The further conversion of these into nitrates is the province of the nitrifying organisms existing in the top layers of porous soils, which attack and retain the nitrogenous particles, at the same time liberating those containing hydrogen; the latter, in their turn, combine at once with the oxygen in the atmosphere, the ultimate result being hydrolysis, or the formation of water.

The experiments of Pasteur which bear specially on this subject, are those carried out in 1876, relating to the fermentative process of putrefaction, and the determination of the various conditions under which the process takes place. Perhaps the most important of all are those by which he was enabled to distinguish between the "aerobic" process of decomposition, or that which takes place in the presence of air, and the "anaerobic" process of putrefaction, taking place in liquids from which air is excluded.

The classification of the different micro-organisms by which the results were obtained was a natural sequence, and Pasteur was then able to distinguish between those putrefactive organisms which are pathogenic (or disease-producing), and those of natural decomposition, which are the reverse. The nitrifying organisms of the soil, i.e. those bacteria which derive their energy and vitality from inert animal or vegetable substances in the presence of air, belong to the latter class, which is by far the larger, while, as the conditions of nature favour their development, they are not only able to carry on their work, but also to propagate and thrive to a degree which enables them to prove fatal to the pathogenic organisms.

Working on the lines indicated by Pasteur, two French chemists, MM. Schloessing and Muntz, carried out in 1877–78 a series of investigations into the purifying action of the soil, the results obtained proving that the mineralisation of the organic matters in sewage was effected by the micro-organisms in the upper layers of porous soils. Dr. Koch, of Berlin, pursuing the subject further, found in 1881 that the organisms in the soil diminished rapidly with an increase in depth, and that at a depth of one metre the soil was nearly free from them.

The work of research had meanwhile been taken up in our own country by Sir John Lawes, Dr. Gilbert and Mr. Warrington, who conjointly carried out that very complete series of investigations on the now historic farm at Rothamsted. It is worthy of note that several years earlier Dr. Voelcker and Professor Way had amply proved the capability of the soil to produce nitrates from the decomposition of nitrogenous organic wastes, though the link in the chain of conversion was unknown to them.

The most important conclusions derived from the Rothamsted experiments were, firstly, that nitrification requires time to commence; secondly, that temperature was found to be a most important link in the chain; thirdly, that antiseptics not only retarded nitrification, but were absolutely fatal to it; and fourthly, that the nitrifying organisms were confined to the first few inches of the soil.

In 1887 Mr. Dibdin, in a paper read before the Institution of Civil Engineers, after alluding to the important part played by bacteria in the destruction of objectionable refuse, expressed the opinion that the antiseptic, or chemical treatment of sewage, was the reverse of nature's method, and that the ultimate treatment would be a combination of chemical treatment with biological. The results of the exhaustive and practical experiments which Mr. Dibdin has since carried out at Barking fully bear out his views of ten years ago.

In more recent years the records of the filtration experiments of the Massachusetts State Board of Health form a most valuable addition to the previous literature; the records kept as to the influence of temperature and the distribution of the organisms being most precise, while the rates of filtration through the different materials used also received minute attention.

In our country, the tendency of the last few years has been to combine a chemical process with land filtration, but as the whole object of the various chemicals used is to precipitate the solids and clarify the effluent before natural fermentation commences, it would seem as though one process was a stultification of the other. Not only is nitrification retarded, but those very solids that are for the time being got rid of by precipitation are required in their mineralised form for the purposes of irrigation, while in their precipitated form they have to be shipped out to sea, or subjected to further treatment such as filter-pressing—in either case, at no inconsiderable cost to the rateable members of the community.

The utilisation of sludge has given rise to many forms of treatment; where there is a sewage farm, certainly the best is the well-known filter-press, as in the portable form of pressed cake, sludge can be dug into the ground and thus got rid of, although its manurial value is certainly not high. There has been, however, a development during the last few years which is well worth our attention. Refuse destructors are becoming an indispensable adjunct to the larger communities, and where one can be built in close proximity to the sewage works of the district, the sludge can be run off into shallow pits or tanks, mixed with refuse, and then burnt in a destructor. The calorific value of the admixture is of course not so high as that of refuse alone, but the system, which is in successful operation at Ealing, Leyton, and other places, certainly has the merit of economy in its favour. The money that is now annually expended in many towns on sludge-pressing would, if capitalised, go a long way towards the cost of a destructor, which can again be turned to profitable account by utilising two hitherto waste products, sludge and refuse, for the purpose of generating steam power.

There can, however, be no universal panacea for the disposal of sewage. London, with its population approaching 6,000,000, and a daily sewage-flow of nearly 200 million gallons, is unique. The present system of treatment and disposal costs 35 shillings per million gallons, every drop of which is wasted. Essex contains acres and acres of land not under cultivation, but specially suitable for irrigation; London contains millions of gallons of wasted sewage, and certainly a large amount of unemployed labour. The question at issue (admittedly one of great magnitude) is whether a combination of Essex, sewage and labour could not effect a material reduction in that 35 shillings?

It would be useless to compare the manufacturing towns of Lancashire, Yorkshire and the Midlands with the chiefly residential towns of the south and west. In the one case the bulk of the sewage is composed of trade wastes, in the other it is mainly domestic. With regard to the former, before any one system of treatment is finally adopted, the aid of the chemist should certainly be invoked in order to analyse the sewage, and to define from that analysis the specific treatment required. Every case of sewage disposal must be dealt with on its own merits, and with due regard to the local surroundings, but I certainly consider that for inland towns up to 10,000 inhabitants, and more especially for rural districts of low rateable value, the prevention of river and stream pollution, which is so largely engaging the attention of our county medical officers of health, can be satisfactorily effected by the preliminary use of upward or roughing filters, the ultimate purification being effected by land, which, if properly utilised, will soon recoup the initial outlay.

The simple method to which I have just alluded, namely upward filtration, specially commends itself to rural districts by reason, not only of the very low initial cost and subsequent maintenance of the necessary works, but also of the material assistance it gives to irrigation by reducing sludge to the lowest possible minimum, and getting rid of the colloids, thus greatly facilitating ultimate purification. It is more particularly in the rural districts of this country that preventive hygienic measures are becoming a rapidly increasing necessity, and such a simple and effective measure as that which I have described, cannot fail to be a beneficial adjunct, if properly applied, as with the low rateable values now prevailing in rural England, every farthing that can be saved from the rates is a relief to both landlord and tenant.

The village pump and the cesspool have had their day. Pure water is a vital necessity to prince and pauper alike, and it is our province not only to supply it, but to provide for its removal after use. No scheme of water supply can be considered complete unless it is supplemented by an efficient drainage system, and in devoting our attention to these works we are endeavouring to benefit all classes of the community, from the Queen at Windsor Castle to the costermonger in Seven Dials, and by so doing we contribute our share to the health, and consequently the prosperity of the nation.

In bringing my address to a conclusion, I may perhaps be allowed to refer to a somewhat peculiar coincidence. The roof under which I pursue a profession founded and enobled by the names of Telford, Rennie, Smeaton, Watt and the Stephensons, has already sent forth two Presidents to the Society of Engineers, both of whom, not only by the works they have carried out, but also by their contributions to the bibliography of engineering, have distinguished themselves in the two very subjects of water and drainage to which I have asked your attention this evening. I need scarcely say that I allude to Mr. Baldwin Latham, President in 1868, and to Professor Henry Robinson, who occupied the chair in 1887. To the last named gentleman I am indebted for the advice he gave on a similar occasion a year ago, namely that future Presidents of our Society should, in their inaugural addresses, deal rather with those branches of the profession with which they were specially acquainted, than with general reviews of a more or less historical nature.

I have endeavoured to adhere as far as possible to Professor Robinson's suggestion, and in thanking you for the very kind reception and hearing you have given me this evening, let me, in return, assure you that during my year of office, I shall spare no effort to do honour to the Society of Engineers.

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March 1*st*, 1897.

GEORGE MAXWELL LAWFORD, President,
in the Chair.

NOTES ON THE PROPOSED BY-LAWS OF THE LONDON COUNTY COUNCIL WITH RESPECT TO HOUSE DRAINAGE.

By James Patten Barber, Member of Council.

The absence of a uniform code of regulations on the subject of house drainage, applicable to the Metropolis, has for a long time caused great confusion and inconvenience to those engaged in the preparation of schemes for such work, as well as to those who have had to execute the work. Arrangements which are permitted in one district are objected to in another; whilst the requirements respecting the work vary considerably according to the views of the members of the local authorities on the subject, some considering that those who build houses should accept the responsibility of providing satisfactory drains and sanitary arrangements thereat, others, that the local authority should themselves prescribe in more or less detail what work is to be done and the manner in which it is to be carried out. The proposal of the London County Council to frame by-laws relating to house drainage has, therefore, raised some hope that in a little while uniformly satisfactory work will be insisted upon in every district in the Metropolis. The County Council have at length prepared draft by-laws which are at the present time under the consideration of the local authorities by whom they will have to be administered. Having regard to the area which will be affected by the proposed by-laws, it seems desirable that they should be carefully considered by engineers and others who will have to comply with them in all drainage works connected with buildings in the Metropolis on which they may be engaged. This paper has accordingly been prepared with a view to bringing the proposed by-laws to the notice of the Members of this Society, and more with a hope of eliciting their opinions respecting them than the expectation of being able to say anything new upon the subject of house drainage.

The proposed by-laws will be made pursuant to Section 202 of the Metropolis Management Act, 1855, by which the Council have power to make by-laws "for regulating the dimensions, form and mode of construction, and the keeping, cleansing and repairing of the pipes, drains, and other means of communicating with sewers, and the traps and apparatus connected therewith." The same section provides that no penalty shall be imposed by any by-law to be made by the Council unless the same shall be approved by one of Her Majesty's principal Secretaries of State. They are primarily applicable to drains, &c., at new buildings, and the extent to which they affect work at existing buildings will be referred to hereafter.

By-law 1 provides that no sub-soil drain shall communicate directly with a sewer, but that a suitable and efficient trap shall be provided with a ventilating opening, at a point in the line of the sub-soil drain as near as practicable to such trap.

This by-law does not prohibit the connection of a sub-soil drain direct to a drain which conveys sewage, or which communicates directly with a sewage drain, but in the author's opinion such a connection should not be allowed, as the foul air from the sewage drain will enter the sub-soil drain as readily as that from the sewer. In all three cases the trap is necessary, and it should be placed as near as practicable to the point where the sub-soil drain joins the sewer or either of the drains referred to, and should be ventilated directly into the open air. The pipes between the trap and the sewer or drain into which a sub-soil drain discharges should be of the same description, and should be laid and jointed in the same manner as those used for conveying sewage. This is necessary in order to prevent the escape of foul air from either the sewer or the drain into the trenches in which the sub-soil drains are laid.

By-law 2 requires that a pipe or channel provided for the purpose of conveying to a sewer any water falling on the roof of a building shall discharge over a trapped gully, or into such a gully above the level of the water in the trap.

An addition to this part of the by-law is needed in order to make it compulsory that water falling upon the roof of a building and upon paths, areas and paved surfaces within the curtilage of the premises shall be discharged into properly trapped gullies and conveyed to a sewer, or shall be disposed of in some equally effective manner to the satisfaction of the local authority. It will be seen that, as the by-law is at present framed, no provision at all need be made for disposing of water from roofs, areas, paths, &c. Unless a satisfactory method of dealing with such water is insisted upon, the practice of erecting buildings or bay windows without eaves gutters and of allowing the rain-water therefrom to fall upon and saturate the ground adjoining the building, and of making what are termed soak-away drains will be continued. It is, moreover, not uncommon for the rain-water from bay windows, porches and porticos to be conveyed therefrom by means of a downpipe which terminates in the ground close to the building, and there is little doubt that unless this is made illegal by an alteration in the by-law, such a plan of disposing of the water will still be adopted.

The second paragraph of the by-law will make it illegal for any solid or liquid matter from a waste pipe from a bath, lavatory or sink, or from a soil pipe, or waste pipe from a slop sink, or from a urinal, to be conveyed into a pipe or channel conveying rain-water. The arrangement at present allowed by many local authorities, by which waste pipes from baths, lavatories and sinks discharge into the open head of a rain-water pipe, will not be permissible under this by-law.

The following are the objections to the arrangement:—

(*a*) Smells arising from the decomposition of refuse and greasy matter accumulated in the rain-water pipe and head.

(*b*) Stoppage of the upper part of the rain-water pipe and head during frost, and the consequent overflow of water from the waste pipes.

(*c*) Inaccessibility of head of rain-water pipe for the purpose of cleansing and removal of obstructions.

The smells referred to in (*a*) might not be injurious in cases where the pipes are situated some distance from windows or other openings to buildings, whilst the liability to the stoppage mentioned in (*b*) can be reduced by placing the waste pipes in the head of the rain-water pipe in such a manner as to avoid splashing.

The author thinks that the by-law should be so framed as to leave the local authority at liberty to sanction the fixing of waste pipes from baths or lavatories so as to discharge into the open heads of rain-water pipes in cases where they are of opinion that the arrangement would be satisfactory; but that waste pipes from sinks should be prohibited from discharging in this way, as the greasy matter and small portions of solid material which are frequently discharged through such pipes would be more likely to cause nuisances than the discharge from bath and lavatory wastes.

The Council's proposal will involve a small increase in the cost of plumbing work at certain buildings where the rain-water pipes might be used to take the discharge from baths and lavatories to the gullies, but it cannot be objected to on sanitary grounds.

Some local authorities require that a rain-water pipe shall discharge into an impervious channel, in the open air, leading to a trapped gully 12 or 18 inches distant from the point where such pipe discharges into the channel. The object of this provision is, no doubt, the prevention of foul air from the drains passing up rain-water pipes when the gully traps become unsealed. Although the arrangement referred to is frequently impracticable in town houses, the proposed by-law of the County Council might be altered so as to allow the arrangement to be carried out by those who prefer it, provided the channels are wholly within the curtilage of the premises. Water falling upon land, roofs, areas or forecourts should not be discharged upon any part of the public way, and it would be for the comfort and safety of the public if the proposed by-law prohibited this being done.

By-law 3 deals with the materials for and the sizes of drains, jointing, concrete round pipes, means of access to drains, trapping of inlets, and other details. The by-law provides that pipes used for drains communicating with a sewer, other than sub-soil drains, shall be of glazed stoneware, semi-vitrified ware, cast iron, or of other equally suitable material.

There appears to be no reason for the words "communicating with a sewer," for the drain referred to in the by-law should be of "good sound pipes," formed of the materials specified, whether it communicates with a sewer, with another drain, or with a cesspool.

The thickness of metal for cast-iron pipes 3 inches diameter, is to be $\frac{5}{16}$ inch, and $\frac{3}{8}$ inch for 4-inch, 5-inch, and 6-inch pipes. The thickness of pipes formed of either of the other materials is not specified, but it seems desirable that the by-law should state that for 3-inch pipes the thickness of the material should be not less than $\frac{1}{2}$ inch, and not less than $\frac{5}{8}$ inch for 4-inch and 6-inch pipes.

Pipes must be socketed and put together with cement or other equally suitable material. Cement is a suitable material with which to make the joints of pipes formed of stoneware or semi-vitrified ware, but lead is a more suitable material for the joints of cast-iron pipes. The by-law should therefore make the use of lead compulsory for jointing cast-iron pipes, otherwise disputes will arise when cement is used for jointing such pipes, and it will become a question for a magistrate to decide whether the use of cement in such cases is a breach of this by-law. The by-law should also specify that cast-iron pipes are to be coated with Dr. Angus Smith's composition, or other suitable material, in order that the pipes may be protected from corrosion and that the inside may be glazed, also that the

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annular space for the lead with which the joints should be made shall, in 3-inch and 4-inch pipes, be not less than $\frac{1}{4}$ inch in width, and in 5-inch and 6-inch pipes, not less than $\frac{3}{8}$ inch.

A drain is to be of adequate size and, if for conveying sewage, it must be not less than 4 inches internal diameter, and be laid in a bed of good concrete not less than 6 inches thick. The width of the bed of concrete is not specified, nor does it seem to be intended that the sides of the pipe should be encased in concrete. A pipe laid in the manner shown in Fig. 1 would comply with the proposed by-law, but such an arrangement would be very imperfect and insecure. An alteration in this part of the by-law is necessary in order to provide that pipes shall be more secure after being laid. Fig. 2 shows the necessary concrete about such a pipe as this part of the by-law refers to. It is intended that underground drains of cast iron shall be laid in a bed of concrete, but a thickness of 6 inches for such bed is scarcely necessary, 3 inches being sufficient for the accurate laying and solid bedding of the pipes. Cast-iron pipes are seldom laid on concrete, but having regard to the ease with which the accurate laying of the pipes can be carried out, and the perfect bedding obtained, this method is much better than the ordinary one, in which the pipes are laid on the bottom of the trench.

A suitable fall must be given to a drain, but no minimum fall is mentioned. The drain must be constructed so as to be water-tight, and must be capable of resisting a pressure of at least 2 feet head of water. A drain must not pass under a building, except where any other mode of construction may be impracticable. So much of a drain as passes under a building must be laid in a direct line, and be encased in 6 inches of Portland cement concrete. Iron drains are not required to be covered with concrete, and they may be carried above ground, if properly supported at each joint by piers or other sufficient supports.

Whenever practicable, means of access must be provided at each end of that portion of a drain which is under a building. All inlets, except those provided for ventilation in accordance with by-law 4, are to be efficiently trapped; and the fixing of bell-traps, dip-traps and D traps is prohibited.

By-law 4 requires that an intercepting trap shall be fixed in every main drain or other drain which shall communicate with a sewer. The trap is to be placed within the curtilage of the building. Means of access to the intercepting trap must be provided, for the purpose of cleaning, either by a separate manhole or other separate means of access.

Intercepting traps and the means of access thereto would have to be inside buildings having no forecourts, vaults or areas in front. In cases of this kind the Islington Vestry has required the manholes containing the intercepting traps to be placed under the footway; their reason for this requirement being the necessity for preventing the entrance of bad smells from manholes placed inside houses on the removal of the covers for the purpose of inspecting or clearing the intercepting traps. Under exceptional circumstances manholes have been constructed inside buildings, and the Vestry has required them to be provided with two air-tight covers, in order that smells might be excluded by the lower cover when the upper one became disarranged or damaged by the passage of people or goods over it. Great inconvenience would be caused by the cleansing of intercepting traps placed, in accordance with the proposed by-law, inside shops or houses, unless there were basements to the premises. It seems desirable, therefore, that the proposed by-law should be modified to the extent of allowing some discretion to Vestries as to the position in which the intercepting traps shall be placed, in the case of buildings having neither basements, vaults, areas, nor forecourts.

The by-law contains no reference to the materials to be used in the construction of a manhole or other means of access to an intercepting trap. If passed in its present form, builders will be at liberty to use whatever materials they choose for these appliances, and however improper the materials or the construction may be, no local authority will have power to interfere. Every advantage would be taken of this by-law by those who seem to think that any quality of material is suitable for drainage work, and who will do nothing properly except under the strictest supervision, or until a summons has been issued against them.

By-law 5 prohibits right-angled junctions, and requires that a branch drain shall join another drain obliquely in the direction of the flow of such drain.

If the words " and as near as practicable to the invert thereof " were added, it would prohibit a branch drain being joined to another at or near the top of the drain, and the risk of solid matter being deposited on the invert, or splashed on the sides of a drain, would be avoided. It is desirable, also, that the use of double Y junctions should be prohibited on account of the tendency of a portion of the liquid and solid matter, discharged by the branch drains, to be washed up one or other of the branches, or up that part of the main drain immediately above the junction of the two branch drains.

By-law 6 requires that the drains shall be ventilated in the manner generally adopted, viz. by two untrapped openings to the drain. One of the openings is to be near the surface of the ground, and is to communicate with the drains by means of a suitable pipe, shaft or chamber. The other is to be obtained by carrying up from a point in the drains, as far distant as practicable from the first opening, a pipe or shaft vertically, to such a height and in such a position as to afford a safe outlet for foul air. The sectional area of every ventilating pipe or shaft is to be not less than that of the drain with which it communicates.

A soil pipe, or the waste pipe from a slop sink, may be used as the pipe or shaft which this by-law requires to be carried up from the drains, provided its situation, sectional area, height and mode of construction are in accordance with the requirements applicable to the pipe or shaft to be carried up from the drains. Any such soil pipe or waste pipe, which has an internal diameter of not less than 3½ inches, and which complies in all other respects with the requirements of the by-law as to the pipe or shaft to be provided for the ventilation of any drain, shall be deemed to provide adequate ventilation for any drain having an internal diameter of not more than 4 inches.

It appears unnecessary to require that where a person chooses to have a 6-inch drain to a house he should be required to fix ventilating pipes 6 inches in diameter, as one of 4 inches diameter would be sufficiently large to ventilate the drain. In all cases it is prudent to place the ventilating opening, which is to be near the level of the ground, as far as practicable from any door, window or other opening to a building, as such ventilating openings, although commonly regarded as fresh air inlets, are found to act at times as outlets for foul air. The proposed by-law does not recognise this, but it might be safer to make the necessary addition, which would direct attention to the matter, as the ventilating openings referred to are often placed near windows or doors, and though provided with valves for the purpose of preventing the outlet of foul air, the valves become defective, or are prevented from closing by the accumulation of dust or other substances which are blown into them.

It is the author's practice not to require the ventilating opening near the surface of the ground to be provided at a building where the drains can be satisfactorily ventilated by means of two soil pipes carried above the roof, and he considers that the by-law should be altered in order to allow a similar practice, and also to permit both the ventilating openings, which the by-law requires to be provided, to be furnished by pipes carried to such a height as will provide a safe outlet for foul air.

The material of which ventilating pipes are to be made is not specified. The by-law should contain provisions similar to those in by-law 8, and the suggested additions thereto relating to soil pipes and ventilating pipes. The by-law should prohibit the connection of a rain-water pipe, or a waste pipe from a lavatory, bath or sink, except a slop sink, to a ventilating pipe.

By-law 7 is directed against the fixing of gullies inside a building in such a manner as to be connected to a drain communicating with a sewer.

There are cases in which this arrangement cannot be avoided, and it is therefore desirable that it should be allowed, subject to the sanction of the local authority.

Fig. 3 shows an arrangement which is very frequently adopted where the rain-water pipe down the front of a building cannot conveniently be fixed so as to discharge into a gully on the premises, except such gully is fixed in the basement. It also shows that the prohibition of gullies inside a building would involve, in the case illustrated, the construction of a deep area at the rear of the building and the fixing of a large amount of piping, in order to convey the rain-water and the waste water from the sink and from the basement floor into a gully outside the premises.

The by-law further provides for the trapping of waste pipes from baths, lavatories and sinks. The traps are to be ventilated into the open air whenever necessary for the preservation of the seal of such traps. The waste pipes are to be taken through an external wall, and are to discharge in the open air over a trapped gully, or into such a gully above the level of the water in the trap. Waste pipes from baths or lavatories should, with the consent of the local authority, be allowed to discharge into the open heads of rain-water pipes, as stated in connection with by-law 2.

The material of which waste pipes and traps are to be formed is not mentioned, nor is the method of jointing them specified. The author has seen houses in which waste pipes have been formed of zinc, the joints being made by pushing the end of one length of pipe into that of the adjoining length, and smearing the junction with putty. Those whose ideas of sanitary work are so low will readily take advantage of the proposed by-law, and provide waste pipes of a similar description unless the by-law is amended, and the material of which waste pipes and traps shall be formed is specified. The only materials which should be allowed for such pipes and traps are drawn lead, galvanised wrought iron, stoneware, or material equally suitable, and the joints should be respectively, wiped soldered joints, screwed sockets, or Portland cement. Another necessary addition to the by-law is a provision that the traps referred to shall be provided with movable caps for the inspection and cleansing of the traps. The necessity for prescribing that waste pipes shall discharge over gullies, or into gullies above the level of the water in the traps, will be appreciated by those who have seen, as the author has, waste pipes discharging into eaves gutters, and even upon zinc flats and iron roofs, which have thereby been covered with grease and filthy refuse, the smell from which has been most offensive and injurious to the occupants of the nouses.

The by-law also requires that the overflow pipes from cisterns and from safes under baths or w.c.'s shall discharge into the open air. The overflow pipes from lavatories or baths should be required to discharge into the waste pipes on that side of the trap which is nearer to the lavatory or bath. This provision has been omitted from the proposed by-law.

By-law 8 relates to soil pipes and the materials of which they are to be formed ; also to the method of connecting traps thereto, and of connecting soil pipes and waste pipes to drains.

At new buildings, soil pipes are required to be placed outside wherever practicable; a proviso not contained in the existing by-law of the Council, which requires that soil pipes to such buildings shall in all cases be placed outside. The proposed by-law, by requiring that soil pipes outside buildings shall be formed either of drawn lead or cast iron, will prevent the use of zinc or stoneware for such soil pipes, such materials being allowed under the existing by-law in consequence of the Council having omitted to prescribe the material of which outside soil pipes shall be formed. No soil pipe is to be less than 3½ inches diameter. The weights of lead and of iron soil pipes are specified, the former being equal in thickness to 8 lb. lead. Cast-iron soil pipes 3½ inches and 4 inches in diameter are to be not less than ¼ inch thick; 5 inch and 6 inch must be not less than $\frac{5}{16}$ thick. The sockets of cast-iron pipes must in no case be less than $\frac{5}{16}$ thick.

It is important that cast-iron soil pipes should have a smooth interior, and that they should be protected from corrosion ; and ventilating pipes, through which no water is discharged, need to be specially protected internally from corrosion, otherwise the bends connecting them to the drains become stopped by rust, and the ventilation of the drains impeded. The by-law should therefore require that all cast-iron soil pipes and ventilating pipes shall be either galvanised or coated inside with Dr. Angus Smith's composition.

It is perhaps the experience of most engineers who have to deal with house drainage, that a cast-iron soil or ventilating pipe perfectly constructed is difficult to obtain. Usually the spigot ends are ragged and weak, the bottoms of the sockets badly formed and sloped so that the spigots get little or no bearing upon them, and the width of the socket insufficient, so that when the molten lead is run in it seldom fills the sockets, but forms a shallow band round the upper part only. With such pipes firm and sound work is impossible, and it appears to be necessary that the by-law should specify that cast-iron pipes used for soil or ventilating pipes shall be made with the spigot ends beaded, with the bottom part of the sockets at right angles to the axis of the pipes, and that the annular space for the lead with which the pipes are to be jointed should not be less than $\frac{3}{16}$ inch wide.

The method of connecting lead or iron soil pipes with the traps of w.c.'s and with drains is the same as the County Council's by-laws at present in force. Whilst the subject of the connections of soil pipes and waste pipes to drains is dealt with in detail in the by-law, it might be still further extended so as to describe the construction of the pipe forming the connection between the soil or waste pipe and the drain. This usually consists of an ordinary bend which, unless encased in a block of concrete, is liable to slip, and the movement would destroy the joints at its upper and lower ends. Better and sounder work would result by the use of a bend with a flat foot or base attached. In all cases where a wiped or overcast joint is referred to, the word "metallic" should be inserted, so that the by-law may read "wiped or overcast metallic joint."

The proposed by-law differs from that at present in force, by requiring that the open end of a soil pipe shall be carried to such a height as to afford a safe outlet for foul air, instead of to a point above the highest part of the roof of the building to which it is attached. An important omission from the by-law is the requirement that a wire guard should be provided for the protection of the open end of every soil pipe.

By-law 9 provides for the ventilation of the traps of w.c.'s, in order to prevent their being syphoned by the discharge from other w.c.'s connected with the same soil pipe. The ventilating pipe provided for this purpose is to be formed of drawn lead, and with wiped joints, if inside a building.

This pipe should in all cases be formed of drawn lead, and if it has an open end, a wire guard should be provided for its protection. The word "metallic" should be inserted between the words "wiped" and "joint."

By-law 10 relates to the construction of slop sinks and the traps and waste pipes connected therewith.

Similar provisions to those referred to in connection with cast-iron soil pipes under by-law 8 should be added to this by-law with respect to cast-iron waste pipes. A wire guard should be specified for the open end of every waste pipe.

By-law 11 requires that the pipes, drains, traps and apparatus connected therewith at any building shall be maintained in a proper state of repair by the owner of such building.

By-law 12 provides that any person offending against any of the foregoing by-laws shall be liable to a penalty of 2*l.* for every such offence, and in the case of a continuing offence to a further penalty of 20*s.* for each day after written notice of the offence from the Vestry.

The last by-law 13 is as follows:—"These by-laws shall, so far as practicable, apply to any person who shall construct any pipe or drain or other means of communication with sewers, or any trap or apparatus connected therewith so far as he shall effect any such works in any buildings erected before the confirmation of these by-laws, as if the same were being constructed in a building newly erected."

From this by-law it would appear that the by-laws will, as mentioned at the commencement of the paper, apply primarily to work at new buildings, and in the case of existing buildings, only to new work thereat, and that the local authority will have no power to require that the repair or reconstruction of drains shall be carried out in accordance therewith. Section 202 of the Metropolis Management Act, 1855, under which the proposed by-laws are being made, does not limit the power of the Council to the making of by-laws for the purposes of regulating the construction of drains, &c., but includes the "repairing of pipes, drains, &c.," in the list of matters respecting which by-laws may be made.

It is of course important that the repair or reconstruction of drains, &c., at existing buildings should be properly carried out, especially as the necessity for the work generally arises from nuisance and illness caused by the defective condition of the drains and sanitary arrangements. Frequently the owner of the building, after the receipt of a notice from the local authority requiring the abatement of a nuisance, will have as little work carried out as possible, and where the whole of the drains need reconstructing to improved lines and levels, he will do no more than re-lay them on the existing lines, and will then defy the local authority to compel him to do more so long as the nuisance is abated. Having regard to such cases it seems desirable that the words "or repair" should be inserted after "construct" in the by-law if the Council is advised that it would not be contrary to the section under which the by-laws are made.

The following is a list of matters not dealt with in the proposed by-laws, and the necessity for by-laws relating to them will probably be self-evident.

1. The submission to the local authority of plans and sections of proposed drainage works.
2. The scales to which the plans and sections are to be drawn, and the particulars which are to be shown thereon.
3. Work not to be commenced until plans, &c., have been

approved by local authority. Manner in which such approval is to be given.

4. Work to be carried out in accordance with approved plans, &c.

5. Time for completion of work.

6. Work not to be covered until inspected and approved.

7. Notice to be given when work is completed and ready for inspection and testing.

8. Persons responsible for execution of work to fill drains with water in order that they may be tested by officials of local authority.

9. Work covered before being inspected and approved to be uncovered within 48 hours after notice so to do.

10. Time to be fixed during which work found contrary to by-laws is to be constructed so as to comply therewith.

11. Thickness of material for drains 9 inches and 12 inches diameter.

12. Construction of gullies, materials of which they are to be formed, and method of fixing.

13. Surfaces adjoining gullies to be formed so as to prevent overflow of liquid discharged on grating, and to be paved with impervious paving where necessary.

14. The construction of urinals, and the traps, pipes and flushing arrangements connected therewith.

DISCUSSION.

The PRESIDENT said he felt sure that the meeting would all join with him in a hearty vote of thanks to Mr. Barber for his interesting paper.

The motion was carried by acclamation.

The PRESIDENT said there were two views with regard to the by-laws. Mr. Barber, in the paper, regarded them from the point of view of the vestry. There were many who, like himself (the President) had to look at the by-laws from the point of view of the owners or tenants of houses for whom they were working. But there was one point upon which they would all agree, and that was the question of unification. A great deal had been heard upon that subject during the last two or three years. All the vestries and authorities under the London County Council ought to have one code of by-laws for house drainage. He had carried out more than two hundred systems of house drainage in nearly every parish round London, and he had not found two sets of by-laws agreeing with each other. As to by-law No. 1, he thought that the direct connection of a subsoil drain with a drain conveying sewage must certainly be prohibited, but he had found the occasions very few and far between upon which he had had to put a subsoil drain in order to deal with ordinary house drainage. As to by-law No. 2, he regarded soak-aways as most objectionable, and certainly a very fertile source of damp walls. They ought not on any account to be allowed. The rain water ought most certainly to be taken away from the house as quickly as possible, and not allowed to saturate the surrounding ground. As to the solid or liquid matter from a waste pipe being discharged into a hopper head, he was sure that there was no necessity to go back to the Norman Shaw system of drainage which, he thought, was pretty well understood to be obsolete now. In cases in which a soil pipe had been carried out of a house on that system to discharge into a hopper head, he had observed that when frost came there was a filling up with pieces of paper and other matter, and there was a pretty sight indeed under somebody's windows. There were certain districts round London, within the area of the London County Council, where that system was still in force. He did not, however, suppose that it would be allowed any longer. With regard to by-law No. 3, it was a wholesome concession to allow 4-inch drains.

In a paper which he read before the Society in 1891, he gave the arguments in favour of allowing 4-inch drains. In many vestries at the present day the by-laws required a 6-inch drain for every single closet. The effect of putting a 6-inch drain to a 3 or 4-inch closet trap was to make an elongated cesspool. Referring to Mr. Barber's diagram (Fig. 3), he assumed that there was, of course, an intercepting trap somewhere. There appeared to be more ways than one of getting over the difficulty. There appeared to be absolutely no reason why they should bring the rainwater pipe down and simply lay a 4-inch drain from the point indicated. Let the rainwater pipe go into it and let the sink go into it; and bring the 4-inch drain into the gully. As an alternative a gully could be placed under the rainwater pipe, and one under the sink waste, and screw caps could be put upon the gullys. Then, in order to ventilate so as not to have an air lock between the trap of the sink and the trap of the gully, they could take a 2-inch pipe off the branch and carry it out at the back. In any case an open gully in a basement of that sort was most objectionable. There would be a pressure on the drain at times, and that was another reason why it should not be allowed. They could either take the drain through at the side or close the gullies and take the drain out at the back.

As to the ventilation of house drains, Mr. Barber did not stipulate for a fresh air inlet at ground level. He (the President) had carried out several systems of drainage where it had been absolutely impossible to get an inlet at ground level. By having a high shaft front and back they got two outlets, and he had found on several occasions by experimenting that there was thorough ventilation, and that to a certain extent the current would follow the direction of the wind that was blowing. If there was any wind at all one pipe became an inlet and the other an outlet. A mica inlet valve was a delusion and a snare.

As to the matters not dealt with in the by-laws, he certainly agreed with Mr. Barber that there was legislation required for every one of those points. He looked upon No. 14, that which related to urinals, as the most important. It was very difficult to get a urinal without some smell hanging about it, and, more particularly, urinals in shop basements. Of course, in West End clubs where a great deal of money was spent and the urinals were well flushed matters were different, but in the basement of shops nasty smells from urinals were frequently met with, and there ought to be very strong legislation on the point. The last few words of Mr. Barber's paper were as important as any, viz. "urinals and the traps, pipes and flushing arrangements connected therewith." A great deal had been heard lately about 3-gallon cisterns, and the water companies were going to compel people who had them to remove them, but he could not agree with the proposed change. The so-called 2-gallon cistern gave a flush of only 1½ gallon. The deep seals now in use certainly necessitated 2 gallons of flushing water. The flushing of urinals was also a very important point; but he believed that the water companies were resisting it. Those bodies ought to be compelled to allow an automatic flushing cistern to be connected with urinals, both public and private.

Mr. Charles Mason said that he, as representing a local authority, perhaps looked at the subject strictly from the author's point of view; but he agreed that local authorities ought not to be arbitrary. The section of the Act under which it was proposed to make the by-laws dated from 1855, and he thought that the County Council ought to be complimented upon putting the powers of that section into force, for the by-laws had been wanted for years, and the Metropolitan Board of Works had done nothing whatever in the matter. One of the greatest drawbacks to municipal work in London was that there was no universal system of drainage by-laws applicable to every parish. It was sometimes said that they could not possibly have the same by-laws for a district like the neighbourhood of the Crystal Palace and a district like Westminster, one being suburban, and the other being closely built upon; but he thought that the by-laws ought to be as inelastic as possible, and to be applied universally in spite of differences in the character of the localities. He believed the vestries' drainage regulations could not be enforced legally; at the same time they were valuable as being a specification for builders of the local requirements. One of the most important omissions in the proposed by-laws was that there was nothing said as to the gradient of the drains. A minimum gradient of 1 in 40 or 1 in 50 ought to be specified, and where such a gradient could not be arranged, automatic flushing ought to be provided at the head of the drain. The question as to the position of the air inlet was one upon which he held a strong opinion. It was immaterial as to height where the inlet and outlet were fixed; but it was a great mistake to confine either of them to within 4 feet or 5 feet from the ground level. The theoretical short and long arm system of ventilation did not always work well in practice. The chief advantage of having an inlet and an outlet was that the air pressure in the drains was relieved. The mica flap, a matter which had not been touched upon in the proposed by-laws, was fast becoming a questionable advantage. He had recently been told by a brother surveyor of a case in which the basement water-closet in a block of mansions of six or eight stories would not work; while that basement closet was in use, two or three closets above on the same soil pipe, although provided with anti-syphonage pipes, were discharged simultaneously, the water in the pan of the basement closet being blown up so that the person using the basement closet was considerably inconvenienced. The surveyor was asked to remedy the defect in the arrangement, and he only succeeded in so doing by having the mica flap removed from the air inlet.

An omission from the proposed by-laws which ought to be strongly urged upon the County Council was the absence of any reference to urinals. Urinals were generally the main cause of foul air in the case of sanitary inspections with which he had been connected. The authorities were doing all they could in his district to get combination closets brought into use and make them act as urinals. The use of iron soil pipes was not proposed to be allowed inside a building. He thought in special cases they ought to be allowed, because many cases had come under his notice in which lead pipes had been unknowingly pierced by nails and wooden plugs by carpenters who were at work upon the premises. Under the proposed by-laws, plans of all drainage works ought to be furnished by the architect, and sent as from the owner to the local authority before commencing the work. At present the builder was the responsible party for drainage work, and the plans sent by him to the local authority, if sent at all, were in many cases very badly drawn; the builder, moreover, sometimes disappeared in three or four weeks after a building was finished, leaving no one actually responsible. As to the size of the drains, the proposed by-laws ought to specify a maximum as well as a minimum size, because a drain might easily be made too large. He had known a 9-inch pipe used under a small house, objection being taken to have one smaller. The intercepting trap on such a drain practically became a cesspool. Again, a 5-inch vertical soil pipe for a couple of closets was insisted upon by the builder, although he was told that a 4-inch pipe would be more efficient and self-cleansing.

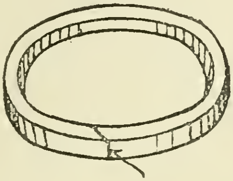
Mr. A. O. Collard said that Mr. Mason had been good enough to recognise that architects had something to do with the matter of drainage, and that was true; but architects owed a great deal to engineers having taken up the subject. The author of the paper had shown wide experience and great ability, and he was glad to notice that the author did not fall in with a recent condemnation of the London County Council for taking up this subject. Architects found that the methods of dealing with drainage by the different vestries throughout London were most confusingly different. If all the different districts united in one set of rules, the result would be pleasant and useful. With regard to the diagram (Fig. 3) exhibited by Mr. Barber, to which the President had already taken exception, to some extent it did seem that Mr. Barber's suggestion was a little old-fashioned, for it was obviously possible that under considerable pressure the gas might be forced into the house, even if there were an intercepting chamber. Mr. Weaver said the other day that there ought not to be a hard and fast rule to deal alike with cottages and with mansions, and assumed the case of a cottage of 20*l.* a year being required to be fitted with drainage of a similar character to that required for a mansion. It, however, appeared to him (the speaker) that the poor man ought to be protected just as much as the rich man. A cottage with perhaps only one closet and one sink, should be drained as well and should have as good material and as good workmanship as the house of the rich man. The same gentleman and other recognised authorities appeared to think that wastes might be taken into the rain-water pipe; but he (Mr. Collard) had always understood that a waste, particularly if it contained anything in the nature of soapsuds, was capable of being most offensive, and might, therefore, be objectionable anywhere. He was delighted to hear from the President that he could not continue to approve of the mica flap. The sooner it was done away with the better. It was only just now becoming known in the provinces. Before coming to the meeting he read in a newspaper an account of what was there described as an "insanitary village." The village had no drainage at all, and the water which was drunk was obtained from wells and was permeated with the contents of cesspools. The doctor of the Local Government Board had reported that the village was in a very bad state. In all probability mica flap valves would be introduced there unless means were taken to stop their use. He hoped that when the by-laws were adopted there would be an appeal from the engineers and surveyors of the local authorities. He had never before heard it stated in public that the regulations of the vestries could not be enforced. There ought to be experts on the appeal committee. If County Councils would adopt the practice of placing upon their committees men who had some technical acquaintance with the subjects with which they had to deal, the procedure would be more satisfactory to the public.

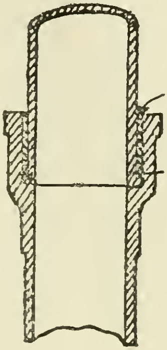
Mr. E. J. HEWARD said that the author had dealt in a very able manner with the clauses of the proposed by-laws. That portion of the paper which referred to matters which the Council had omitted was of the utmost importance. In his district the authorities had a great deal of trouble in getting plans. Some of them were, as Mr. Mason had said, very roughly prepared. He observed that the by-laws provided that ventilating pipes were to be carried up to a certain height above the building to which they were attached. He had a case the other day in which the open end of a soil and ventilating pipe was carried up about 4 feet above the roof of the closets, which were an addition to the annexe to the main building, the roof of the closets being about 2 feet lower than the roof of the annexe. The open end of the pipe came in a direct line with two windows, and if it had been carried up above the roof of the annexe building, it would have been in a direct line with an attic window, and within 20 feet of such windows. He thought it ought to be required that a ventilating pipe should be carried up to a certain height above the main building. He hoped that the County Council would take up the matter of the by-laws very seriously, and that the same system would be brought into operation in every district throughout the Metropolis.

Mr. J. PAGET WADDINGTON said that the by-laws of the County Council proposed to make the inspection chamber in connection with the intercepting trap, so that if the intercepting trap was in front of the building, the inspection chamber must be at the same point. It had been pointed out in the paper that that arrangement would involve placing the inspection chamber in the basement of the house, if there was a basement, or under the floor of the shop or living room if there was no basement. He had had some experience of another system which on the face of it, perhaps, did not look very satisfactory, but which in practice answered very well. In cases in which there was no space for the inspection chamber in front, it had been placed in the yard or garden at the back of the building, and the intercepting trap had been placed just without the front wall of the building with a plunging arm against the wall of the building underneath the footway paving. That arrangement had answered remarkably well, and it appeared to him to be a good one for adoption in cases in which there was no ground in front, in preference to having the inspection chamber within the building. As to plans, he thought that they should be deposited in duplicate, and that a signed copy should be returned to the person who deposited them, and kept on the works for the inspector to refer to.

Mr. A. J. Gale said that he was not at all sure that the by-laws which had been proposed were likely to get those connected with the subject finally out of their difficulties. Further and important changes would probably follow the by-laws, as it was impossible to foresee the exact working in detail. The discussion would be of the greatest use in bringing them nearer to the desired object; and yet many of the points which had been raised showed that there was still a great deal of diversity of opinion and room for discussion. It would be well if some recommendation could be made from the Society to the framers of the by-laws. Some of the points which had been raised in the discussion had never before been started, and showed the need for full conference among those interested before finally fixing the shape of the new regulations.

Mr. E. H. G. Brewster, alluding to the question of the joints of pipes, stated that he used in his practice cast-iron drain pipe with spigot and faucet ends similar to those commonly used for water pipes, as shown in the annexed diagram. The joints were made by means of a split ring of cold lead, which was driven to the bottom of the socket and caulked, and molten lead was poured on to the split ring until the socket was filled, and when cold was well caulked. The plane of the split in the cold lead ring was in a line with the axis of the pipe, so that the caulking the ring received caused the split to be closed. By using this method of jointing, the pipes were well centred; and, as no gasket or tarred rope was used, there was nothing to rot away and spoil the joint, and there was no danger of a large quantity of rope, &c., being used by the workman, and but little lead.





With regard to the thickness of the concrete under the pipes, he did not think that the 3 inches recommended by the author would be sufficient. He should certainly use 6 inches, and he did not think that the extra 3 inches would be wasted for cast-iron pipes, as, in the event of a pipe being corroded away, the 6-inch layer of concrete would practically act as a pipe, and would be of considerable use in preventing leakage. As to intercepting traps inside a building, they were decidedly harmful in that position. Inflammable gas, as well as noxious gases, would accumulate in intercepting traps; as a proof of that, he might mention an instance in which a butler opened a trap to examine it by means of a light, and was seriously hurt through the firing of the accumulated gas therein. There ought to be a provision in the new by-laws limiting the time that an owner should be required to wait for the decision of a local authority. He illustrated that by stating that a drain at the back of some houses in which he was interested was opened by order of the vestry inspector, and left for three months waiting for the decision of the local authority as to what was to be done, and it was not until he complained to the vestry as a body that anything was done.

Although the question of inspectors of nuisances had not been touched upon, he stated that those officers, instead of being under medical men who knew nothing of the arts of construction, ought in his opinion to be under the surveyors or engineers of the authorities. The inspectors' powers were very large, and they (the inspectors) ought to be under the control of someone who knew more than they did themselves of the construction of drains and the fitness of materials. A medical man might know when a bad smell was prejudicial to health, but, as a rule, he would know very little about the way in which to put the matter right.

As to the flushing cisterns for water closets being capable of holding 3 gallons instead of 2 gallons, he (Mr. Brewster) thought the lesser quantity was sufficient, although no doubt the larger quantity might make doubly sure of the solids being carried away; so would 10 gallons, but as water was not stored, filtered, pumped and delivered at houses for nothing, neither was it got rid of for nothing, and for those reasons he was content with what was sufficient. The use of the three gallons flush throughout the Metropolis would occasion an extra cost of 91,250*l.* a year for the pumping of the water to the houses only, taking the cost of pumping at 4*d.* per 1000 gallons, and the population at 5,000,000. At 3 per cent. that represented a capital of three millions of money, independently of the capital which would be involved in providing storage, &c., for the extra water used.

Mr. Bernard Dicksee said that one indirect operation of the by-laws had been quite lost sight of. No. 6 required that the ventilating pipe should be in all cases equal in diameter to the drain. If that resulted in the employment of a 4-inch drain, so far so good. But there were cases in which a 6-inch drain would be necessary. In a case of that kind, the ventilating pipe would have to be 6 inches. In another by-law there was a provision that a soil pipe might be used as a ventilating pipe where it complied with the requirements of a ventilating pipe. The effect of that would be that if there was a 6-inch drain there would be a 6-inch soil pipe. Anything more unsanitary it was impossible to conceive. A 3-inch soil pipe was large enough for all practical purposes, and in most cases was the best size to employ. There should be a minimum size of 3 inches (instead of 3½) and a maximum of 4 inches. With regard to the mica flap ventilators, so-called, they were most insanitary. In one district there were hundreds of cases in which the mica flap ventilator, inserted to ventilate old drains, was placed just under the parlour window, and the mica flap being knocked off, the pipe emitted foul gas into the building. The new by-law required the untrapped opening to be on the level of the ground; that would prohibit the use of the mica flap. It was impossible to ensure that the air would go in a certain direction because the engineer put a few arrows on a drawing. As to the discharge of wastes, traps were not only unnecessary in short wastes, but most undesirable, being obstructions to the flush of ventilation. The principal thing was to see that the area of the outlet from the bath or lavatory, or other fittings, was at least equal to the area of the pipe. It was very usual to put a ¾-inch outlet on a 1½-inch waste pipe, and the pipe necessarily got foul.

Mr. H. G. ASSITER said he thought the Society would be very much obliged to Mr. Barber for the able way in which he had dealt with the subject. The public also were indebted to him for bringing the matter forward. The making of the by-laws would benefit practitioners and the owners of property as well as the local authority, because they would now know what they were required to do. At present a great deal was left to the caprice of officials, and the vestry's requirements differed greatly in different parishes. He agreed with Mr. Dicksee in what he had said as to waste pipes from lavatories and sinks. Although danger might arise from an open head which would be liable to foul, such a danger was less likely to arise than the danger which would arise from putting a waste pipe into a closed pipe. Whether a waste pipe from a lavatory, or bath or sink, was long or short, it should certainly be trapped immediately under the outlet of the apparatus. A pipe was sure, in course of time, to get foul to a certain extent, even if only waste water passed through it. The warm air of a building tended to draw in the cold air from the outside, which would be fouled in its passage through the pipe. He did not find anything in the by-laws to necessitate the ventilating of a waste pipe. If a waste pipe was carried into a closed pipe, it was most desirable that the main waste-pipe should be ventilated in the same manner as a soil pipe. Mr. Barber had suggested the use of Dr. Angus Smith's solution. He (Mr. Assiter) had nothing to say against it, but all its benefits disappeared long before the pipe was worn out. He thought it would be a very bad precedent for the County Council to specify the use of anybody's patent. The by-laws required that stoneware pipes should be encased in concrete, and in his opinion stoneware was the very best material for drains. Iron pipes might, under the proposed by-laws, be carried above the ground on brick piers. Cast-iron pipes were very often full of air holes and sand holes, and it was quite as necessary that an iron drain pipe should be imbedded in concrete as that a stoneware pipe should be, where it passed under a building. Remarking on by-law No. 4, Mr. Barber said that it contained no reference to the materials to be used in the construction of a manhole or other means of access to an intercepting trap. Under sect. 61 of the Metropolis Local Management Act of 1862 the local authority had power to specify the materials and the manner in which the drainage should be carried out. So he failed to see the necessity of any by-law for the purpose. He agreed that it was not necessary for the ventilating pipe to be equal in size to the drain. The President had pointed out an alternative scheme to that shown in the diagram (Fig. 3). The only objection to it was that it would prevent the floor from being washed down. Where he (Mr. Assiter) had had occasion to put a gully inside a building, he had always put an air-tight cover over it, ventilating the gully by means of a pipe to the outer air. The author said that the only materials which should be allowed for certain waste pipes and drains was wrought iron. Was not that a misprint, and did not the author mean galvanised cast iron? The jointing of the pipes was very often very unsatisfactory. There was a method of jointing soil pipes by means of a combined socket which was very often used. It was in use in two large hotels in the immediate neighbourhood of the Meeting. The ends were placed in a socket, and an ordinary copper bit joint was placed round it. That was not to be commended.

The jointing of closets to drains had not been dealt with in the paper. He had found ordinary pedestal closets connected in a very unsatisfactory way with putty. That should be prohibited by by-law, and the traps of the closets, where they were connected with soil pipes, should be made of lead, so that there should be no weak joint except above the water line of the trap. It was very essential that a wire guard should be put on a ventilating pipe. A few days ago he met with a case in which twigs and straw had been deposited in a ventilating pipe by birds, to the depth of 18 inches, which could not have happened had a guard been fixed. As to the scale upon which a plan should be made, he thought that ought to be left to the discretion of the person sending in the plan. He was very much opposed to giving local authorities any further facilities for delaying work—it ought not to be necessary for people to have to wait until they had approved the plan. Sanitary work had to be done in accordance with the law, and if anyone carried out work improperly the vestry could always require it to be re-executed. As little as possible should be left to the discretion of the sanitary inspector. While their status had much improved during the past few years, there were still many of the inspectors who were quite incompetent, and the more incompetent they were the more they were inclined to contend for their rights, and to use their very large powers in placing difficulties in the way of the carrying out of sanitary improvements.

Mr. F. L. Dove congratulated Mr. Barber on the paper. The author had drawn attention to several matters in connection with the by-laws, which, although they were very simple in themselves, were likely to be a fruitful source of controversy when they came into force. For instance, with regard to the concrete, as in Fig. 1, nobody supposed that the County Council contemplated that anything as absurd as that would be carried out; and yet a litigious man could insist upon it. As to the question of concrete, he felt strongly disposed to leave it to the local authority to determine whether concrete should be used, and what the thickness should be. In certain cases concrete was totally unnecessary, as, for instance, in a sound gravel soil. On the other hand, where the ground was bad, six inches of concrete would not be sufficient to keep the pipes sound. He should go as far as two feet of concrete under certain conditions, and even have hoop iron bedded into it where there was inequality in the nature of the soil. With regard to the diagram, Fig. 3, which had been referred to, the method there shown was to be used where it was impossible to get a manhole outside the building without going on the public way. As far as his experience went he did not see the slightest objection to a manhole being placed outside, a manhole cover being no more objectionable than a coal plate. He agreed with what had been said in condemnation of the mica flap. There was nothing to prevent the ventilating pipe being carried up the front of a building, and no objection was likely to be raised to it, unless the architectural design of the building was a very feeble one.

Mr. T. F. Bryen disagreed with Mr. Barber with regard to waste pipes from sinks in houses of the ordinary class. He thought it was wholly unnecessary, and not altogether sanitary, to insert a trap in a short length of waste pipe passing through a wall from a sink. He believed that a 2-inch stoneware pipe, properly vitrified and properly fixed, was a better way of disposing of the slop coming from a sink. If the by-law bearing on that could be amended it would be an advantage. Traps were frequently stopped through carelessness. He attached a great deal of importance to the list of matters not dealt with in the by-laws. He held a very strong opinion that where it was possible to get a drain outside a house, it should be so placed. He did not know whether that was a matter which could be brought within the by-laws.

Mr. A. J. Fearnhead said that the subject of the paper was one which wanted a good deal of discussion before the by-laws were settled unalterably by the London County Council. There was a point connected with the inspection chambers which had not been touched upon, and that was a provision for the periodical inspection of those chambers. He thought the by-laws should require that they be inspected once a year, or at some other stated interval.

Mr. J. J. Rawlings said he thought it was a mistake to suppose that a waste pipe going a short distance was the only one that needed to be kept clean. Surely it was as necessary to keep clean one of 60 feet in length as one running only a few feet. With regard to subsoil drainage, the fact that the inlet of a subsoil drain might be below the surface of the drain seemed to have been forgotten. In such a case the temporary obstruction of the sewer or of the interceptor would cause the sewage water to bank back and flow into the subsoil drains. He had known that to happen in several instances. A flap should be provided in such cases to prevent or minimise the danger. An allusion had been made to a remark of Mr. Weaver. He (Mr. Rawlings) thought that what Mr. Weaver had in view was the possibility of substituting pipe shafts instead of manhole chambers for inspection of interceptors, for it was outrageous to call upon a house owner to make a manhole 6 feet or 8 feet in depth to afford access to a trap which, in small houses of the artizan class, was often the only point in the chamber that might require attention; a pipe shaft was all that was needed to remove obstructions, and to apply the water test by the aid of a pneumatic ball.

Mr. Barber, in reply, said that the diagram (Fig. 3) to which the President had referred was not intended to indicate every method by which the rain water and the water from the sink in the basement could be got away without having gullies in basements. It was only intended to represent that which would obviously be the cheapest way. He quite agreed that it was desirable to avoid having a gully inside the house, but he could not see that it was necessary to go to the very great expense of constructing pipes as shown, or even another drain running from the front to the back. Very often the water used in the basement was discharged into a channel which was taken through the rear main wall to a gully in an area at the rear of the building, and, in the event of the gully becoming unsealed at the back, part of the foul air could go up the area and part of it might come into the basement. At the same time it was desirable to have the gullies outside wherever possible, but in cases such as those shown in Fig. 3, and where basements were used as wash-houses, or had sinks placed in them, it seemed unnecessary to prohibit the fixing of gullies inside the buildings. He was very pleased to hear Mr. Mason say that in his opinion the by-laws should be inelastic. To his mind it was absolutely necessary that the by-laws should be detailed and specific, not only for the sake of the person who was responsible for superintending the work, but also for the sake of the person who had to carry the work out. It was complained that the regulations in the parish of Islington were much too prolix. They had been made full with the special object of securing uniformity of action by the whole of the inspectors, so that they should be able to get absolutely the same thing done in the whole parish, the inspectors in which numbered nineteen or twenty. It was much better both for builders and for inspectors that the by-laws should be specific and inelastic. He was also pleased to hear the opinion which had been expressed with regard to the use of mica flap valves. Mr. Dicksee had used the words "mica flap ventilators, so-called." He had never before in any meeting been able to get very much support of his views as to the so-called fresh air inlet and the mica flap valves. He had instructed his own staff never to speak of pipes furnished with those valves as "fresh air inlets" to persons who were carrying out drainage work, but always to speak of them as "ventilating pipes," for it was impossible to tell which way the air would go, and they sometimes acted as outlets. He was afraid that it would be impossible to employ cast-iron soil pipes in buildings, on account of the liability of buildings to settle and thereby cause the cast-iron pipes to crack. He feared that Mr. Collard would not have the luxury of appealing against the vestry if the by-laws were passed. He should always advise a builder to appeal against the requirements of a vestry if he thought them unreasonable. The surveyors of the local authorities did not mind such appeals if there were differences of opinion. As to the 6-inch pipe for a house drain, he could remember the time when it was insisted upon for the drainage of a house, and when two houses were drained together a 9-inch pipe was demanded. He supposed that if six houses were drained together they would have had a pipe 2 feet in diameter. He quite agreed with Mr. Assiter's remark that it was undesirable to specify any particular person's patent; but most people knew that the patent of what he had called in his paper Dr. Angus Smith's composition expired twenty years ago or more. The compound, however, was still called by the name of the inventor. As to the difficulty in detecting air holes in iron pipes, Mr. Assiter seemed to forget that the by-law required that the drains were to be water tested, so that any air holes or flaws in the pipe would be detected by the testing, even if the pipes were not tested at the foundry. The same gentleman had asked whether galvanised cast-iron pipes might not be used for waste pipes. There were several reasons against the use of such pipes. One was that cast-iron pipes of small diameter could not be cast as smooth as was necessary for waste pipes. Then they would not be economical when many bends were required in taking pipes from a sink, lavatory or bath, into the open air. Further, they would be exceedingly heavy, and would require something underneath the sink or the lavatory, or the bath, to hold them up.

He thanked the Meeting for the very kind way in which they had received the paper, and also for the expressions of opinion which had been given. It was a great advantage for an engineer who held a public position to have the opinions of his fellow professionals who were in private practice. He hoped that good would result from the discussion.

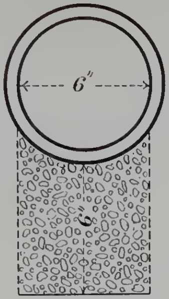


Fig. 1.

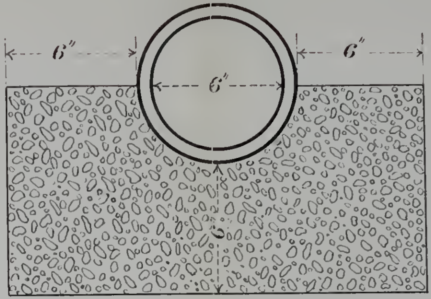


Fig. 2.

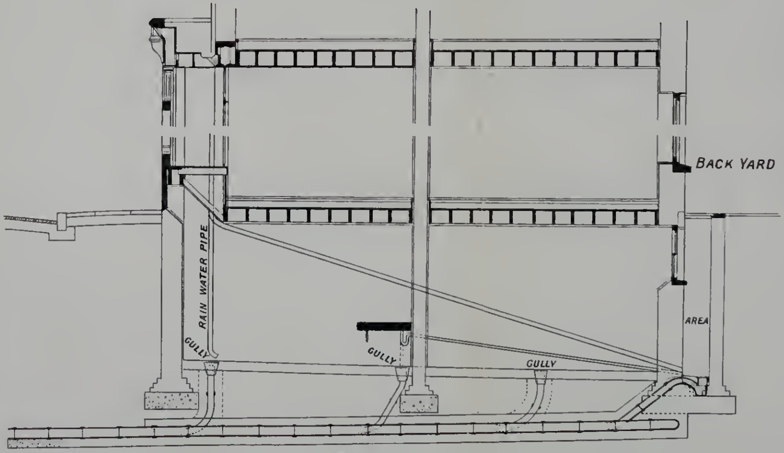


Fig. 3.

E. & F. N. Spon Ltd, London.

April 5th, 1897.

JOSEPH WILLIAM WILSON, JUN., PAST-PRESIDENT, IN THE CHAIR.

THE RATING OF ENGINEERING UNDERTAKINGS.*

By PHILIP MICHAEL FARADAY.

THE question of the assessment for rating purposes of our great engineering undertakings, such as railways, canals, gas and water works, is necessarily one of vital interest to all engineers connected either directly or indirectly with the management of such concerns, and the importance to them of some knowledge, however limited, of the method in which undertakings under their control are assessed, has suggested to the author that a paper upon the subject—which will, it is hoped, give scope for an interesting discussion—may not be entirely without interest.

It is common knowledge that no town of any importance is without its railway system and its gas and water supply, but the extent to which these undertakings contribute to local taxation is comparatively little known; and still less that in some rural parishes, through which the trunk line of a large railway company passes, it sometimes happens that the proprietors of the railway pay as much to the parochial authorities as the total of the other ratepayers combined. This on the face of it appears to be an injustice, and more especially so when one considers that the acreage of land in the parish occupied by the company is infinitesimal compared with that occupied by the other contributors to the rates. Primarily, however, it must be borne in mind that the fundamental principle upon which every hereditament is rated, whatever that hereditament may be, is its rental value; the last definition of the term "gross value" by statute being, "The annual rent which a tenant might reasonably be expected, taking one year with another, to pay for a hereditament, if the tenant undertook to pay all usual tenant's rates and taxes, and tithe commutation rent-charge (if any); and if the landlord undertook to bear the cost of the repairs, insurance, and other expenses (if any), necessary to maintain the property in a state to command that rent." At the first glance it would appear to be inequitable that the railway company should contribute out of all proportion, as regards the area of its property, to the other ratepayers ; and that one piece of land adjacent to another should vary so largely in value for assessment purposes ; and one might almost be led to hastily conclude that the hard-and-fast rule that trade profits should not be rated had been broken. Upon consideration, however, this will be proved to be an erroneous conclusion, and it will be seen that the old axiom of a property being worth what it will fetch may well be applied here ; for, in the event of the railway company not possessing the fee-simple in the land, they would be willing to give a large rent, and it is upon this hypothesis their assessment is fixed.

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* The Bessemer Premium was awarded to the author for this paper.

The method of ascertaining the hypothetical rental value is one of great moment to every parishioner, for, theoretically, as the total rateable value of a parish increases, the rate in the £ diminishes, and consequently the small ratepayer possesses an obvious advantage in a company occupying land in the same parish in which his own property is situated. At the same time, it must not be lost sight of that the law is framed with the prime object of equality, and although a company is, perhaps, better able to pay more than its just share of the local burdens, as compared with an individual occupier of property, it was not the intention of the Legislature that it should be called upon to do so, and any policy initiated by the local authorities tending in that direction cannot be too vehemently denounced. On the other hand, a wealthy company has a decided advantage over a poor parish, in so far as it has greater facilities for legal proceedings, and in many cases the dividends to its shareholders are held in higher esteem than the obligatory duty which it is under to each ratepayer in every parish in which it is a taxpayer. This, however, is somewhat a digression as regards the direct subject of this paper, but the excuse must be the importance of the point, which could not be altogether overlooked.

The facts, firstly, that trade profits are not rateable, and secondly, that the rateable value of such undertakings as canal or railway companies are calculated upon their receipts and expenses as going concerns, is to the casual observer irreconcilable, but upon carefully studying the matter, the equity and fairness of both of these rating rules are fully demonstrated.

When the assessment of any hereditament is being considered (such hereditament being occupied by the owners), the object, as has been previously stated, is to find the rent which a hypothetical tenant could afford to pay a hypothetical landlord for a similar occupation, and the first question which must arise is as to how much of the property would belong to the landlord and how much to the tenant—for it must not be forgotten that, with the exception of a few incorporeal hereditaments, it is the land itself which is liable to the rate, and its value *quâ* land only is increased by the uses to which it is put. In the case of a large company (whose system extends possibly from the south to the north of England), when the published accounts are submitted for the purpose of making a valuation of a small isolated parish, say, for instance, in Yorkshire—for these accounts are practically the only data upon which an equitable assessment can be determined—the situation can be appreciated when we remember that only this one portion of the whole undertaking is to be assessed, and that for this purpose it has to be assumed that it is possible for a tenant to enter into possession of it, consequently the rent which he could afford to pay for this part alone has to be estimated from the accounts.

Now, it would be a comparatively easy task for a properly constituted body to determine the rental value of the whole system of the London and North Western Railway, for example, and then to apportion the rateable value to the several parishes claiming a share, according to the length of line in each parish. But such a principle of assessment has been set aside by the courts, and justly so, as it must be patent that an occupier of property in some rural parish should not have the advantage of a contribution to the common fund of another ratepayer, owing to the fact of such ratepayer being a company which has property extending through many parishes, and that the average rateable value per mile of the whole of their system allows a higher assessment to be placed upon the property in this rural parish than would otherwise be the case. The same injustice is suffered in those parishes where, through this equalisation, the company's assessment was not as high as it should be. One illustration will make this point clear. Take a mile of railway at Paddington and another at Penzance. Obviously, a landlord could command a higher rent at Paddington than at Penzance. This being the case, why should the ratepayers of Paddington pay more, because one of their number pays to Penzance taxes which are justly payable to Paddington? The principle, then, to be borne in mind when assessing these extensive undertakings is that they shall be assessed in each parish according to the value of the occupation in that parish.

The method of arriving at the rateable value of a hereditament on the receipts and expenses principle, is briefly as follows.

The gross receipts have first of all to be obtained, and from these have to be deducted—

(1) The working expenses.
(2) Management expenses.
(3) Government charges (if any).
(4) Rates and taxes.
(5) Rental value of dead works.

The result obtained is the gross profit accruing from the undertaking. The hypothetical tenant, who has, it is assumed, sunk capital in the concern, would then require a return by way of interest, &c., for his money; and a sum to represent this amount has now to be deducted from the gross profits to satisfy his claims, the residue being the amount he could afford, and would be willing to pay the hypothetical landlord for his occupation—in other words, the gross value of the property. From this sum the usual statutable deductions are made, viz., those for maintenance, &c., and the result will be the rateable value, upon which basis most of the taxes are paid.

This, then, is the principle which is adopted when assessing railways, canals, gas and water companies, &c., and its application, although varying in some slight details as the character of the particular hereditament varies, may be taken to be practically similar in every case.

Dealing more particularly with railway companies, the question of parochial receipts and the working and management expenses may be passed over, as they chiefly resolve themselves into a matter of book-keeping; although it is not for one moment suggested that a keen appreciation of the purpose for which these amounts are taken from the accounts should be lacking in any one whose duty it is to compile them. The result, if this knowledge be wanting, would probably be useless; but time will not permit of the author going thoroughly into the details of the various sums which would be included under these headings.

Perhaps the most important item in the valuation of a railway company is the hypothetical tenant's capital. It may not be widely known that, as a general principle underlying railway legislation, a railway company has not exclusive use of the right of way over its railroad, and that any private individual has the privilege of running his own engine and carriages over the line of way constructed by the company on payment of tolls, in the same way that a barge owner is allowed to carry freight over a canal by paying to the canal company certain tolls for the usage thereof. It follows, therefore, that in dealing with these enormous undertakings it has to be assumed that there are two capitals employed, one belonging to the hypothetical landlord, and the other to the hypothetical tenant. As for the engines, carriages, &c., rent is not paid—land only being rateable; it is clear that the hypothetical rent or gross value is paid only for the privilege of using the line of way. The land occupied by the running lines, therefore, constitutes the hypothetical landlord's property, and the return which he is assumed to receive for his capital sunk in this property is the gross value, or, as it is sometimes termed, the landlord's share. Consequently, we have to deal only with the interest, &c., derived from the hypothetical landlord's capital, and have no occasion to ascertain the capitalised amount of this interest.

With tenant's capital the situation is different. Although, as has already been pointed out, a hypothetical tenant is assumed to exist, the capital which he would require cannot be assumed; this figure has to be worked out upon the basis of the occupation—that is to say, each hereditament has to be dealt with as it exists at the time the valuation is made, the uses to which it is then put and no other considerations whatever must enter into the calculation. The constituents of a tenant's capital of a railway company would consist chiefly of the rolling stock, conveyances at the various termini, horses, &c., tenant's stores, furniture and fittings at the stations, all non-rateable machinery and tools; in addition to which he would require a certain sum of money as working capital. The task of ascertaining the tenant's capital for a railway of any importance is necessarily one of great difficulty, and a question might arise as to whether the various items should be taken at their prime or first cost, or if they are to be estimated at their present value? The answer to this point is that they are to be taken at their actual value, above or below their cost when first purchased by the company; because an incoming tenant would say, "What rent can I afford to pay upon taking over this property? It is obvious that the amount I can pay as rent must depend upon the deductions to be made from the gross earnings in respect of profits, interest, &c., due upon my capital invested therein, and I must, therefore, calculate these profits on the amount of capital actually required to be expended on the stock; not on what may have been the value of the stock at another time, or in other hands." The present cost, therefore, is what has to be ascertained, and when this amount has been fixed, the percentage to be allowed the hypothetical tenant as his share of the profits, &c., of the undertaking, must be determined. Upon this point probably more cases are contested than upon any others which arise in connection with a rating appeal.

There are three distinct sums to which he is entitled:—

(1) Interest on his capital.
(2) Trade profits from the concern.
(3) A sum to be set aside for risks and casualties.

Custom, to a large extent, is responsible for certain amounts, and there is nothing more difficult to set aside than an unwritten law which is more or less universally adopted. Five per cent. is usually allowed for interest, 10 per cent. for trade profits, and 2½ per cent. for risks and casualties.

With regard to the amount for interest, it is a well known fact that nothing like five per cent. can be obtained at the present day for money invested in trust funds, and, undoubtedly, the rate of interest for money in the market should influence the rate to be allowed a hypothetical tenant who, having invested his capital, is allowed by law a certain sum in the form of interest; putting aside altogether the question of trade profits which he also derives from the concern. The interest allowed on the tenant's capital, therefore, is, as a rule 17½ per cent., but a lower rate is sometimes contended for.

The stations, sidings, &c., of a railway company (and these may be termed "Dead Works") are assessed upon a different principle to that of the running lines, and, when making a valuation of the line, a deduction should be made from the gross receipts to allow for the rent which a tenant would have to pay for the use of the stations over the whole of the system. Of course, the gross value of the stations is the rent which the railway company would be willing to pay for them under the statutory terms. The amount of money taken at a station does not affect the rateable value of it, for stations are largely for the convenience of the company to facilitate the collecting of their tolls, the money being earned over the whole route by which the passengers and goods are conveyed. To estimate the rental value of a station it is necessary to ascertain its cost of construction; and by taking a percentage upon this, and adding a percentage upon the value of the site, a figure representing the gross value is arrived at. Signals and sidings are included in the valuation of the station, as, theoretically speaking, if a train ran from one terminus to another, and there were no intermediate stations, no signals would be required. They are only erected because of the stoppages which take place and the many stations situated on the route of a great trunk line. The case, however, with regard to signals at a junction is different, as these are included in the valuation of the line.

The foregoing deductions having been made from the gross receipts, the gross value of the undertaking is arrived at, and from this has to be deducted a sum to allow for the maintenance and renewal of the permanent way. It would be very difficult to determine the sum of money necessary for the maintenance of any one mile of railway. Cases could be cited without number, but we should be no nearer fixing an amount which might be laid down as an invariable rule. A railway company could probably give the actual expenses incurred on any particular section, as the method they have of keeping their accounts would allow of this, but the sum for renewal is so involved with that for maintenance, that it would be almost impossible to separate the two; indeed, no one could say from an examination of the accounts where maintenance left off and where renewal began. Repair and renewal, in point of fact, go on simultaneously, and when making a valuation of a railway company an inclusive figure to cover both items is very often estimated. In ascertaining this amount, it must be borne in mind that, although the parochial principle is to be adopted, there are certain expenses connected with the maintenance of tunnels and viaducts; and, notwithstanding that these are incurred in the parish for which the valuation is made, they must not be charged wholly to that parish, as the tunnel or viaduct, as the case may be, is contributing to the earnings everywhere, and without either or both the traffic on each side of the particular parish could have no existence. It must be apparent that the figure (unless given by the railway company) is an estimate, and consequently the amount of train mileage must have considerable bearing upon the question; as, where the traffic is heavy the expenses will be greater than where it is light, although not necessarily by any means in the same proportion.

This deduction having been made, the rateable value in the parish is arrived at, but it must be obvious that in a great number of cases it will be found impossible to adopt this principle, for it is a *sine quâ non* that to arrive at a successful result the amount of parochial receipts must exceed the amount of the deductions, or otherwise there would be no rateable value. On the other hand, every branch of a railway company's line must of necessity have some value to the railway company, for if this were not the case an application would be made for permission to close such part. Consequently we have the following position. On the system of most of our large railway companies there is usually to be found one main or trunk line with several branches; many of these branches are worked at a loss, but they are the means of bringing traffic to the main line as feeders, and as such they are material sources of wealth to the company. In the event of the whole system of the railway company being contained in one parish, the difficulty of the assessment of such would be easily surmounted, but the parochial principle having to be adopted, owing to its running through many parishes, the local receipts and expenses are those only which can be taken into account. It follows, therefore, that in certain parishes railway companies may be in the possession of property which contributes nothing to the local rates, for although there is undoubted value to the present occupier, the question which really determines the assessment is—What is the value of this property *per se* to a tenant if it were to let? The answer to this of course must be *nil*, for it would be impossible to find a tenant for a property of a trading concern the expenses of which exceeded its receipts. The railway company, however, does not gain from this cause, as it has to pay additional rates elsewhere. Should it so happen that in one parish there are two portions of line, one making a profit and the other working at a loss, the profits made upon the one line must, first of all, be devoted to paying off the deficit upon the other, after which the apportionment for the rateable value should be made.

With regard to the rating of canals, great similarity exists between this class of property and that last dealt with. They have both the same common object, although the business of carrying passengers by canal has largely diminished since the introduction of railways. Formerly, land over which a canal passed was rated as if it were not applied to the purposes of a canal, but as if it had remained in the hands of individual owners and was used for ordinary agricultural purposes. Canals are now rated upon the principle of their receipts and expenses, this principle having previously been explained in the case of railway companies, but the buildings and reservoirs necessary for the proper working are assessed upon a percentage of their structural cost, these corresponding to the stations of a railway company.

When making a valuation of a gas or a water company the same principle is adopted; but there is one difficulty less to contend with than in the case of a railway, for with regard to the live mains the parochial principle is only applied to a gas or water undertaking as far as the receipts are concerned. A valuation in these cases is made of the whole concern, and after the division is made between the dead works and the live works, the rateable value is apportioned to the several parishes in which the hereditament is situated, in the same proportion as the rateable value of the whole bears to the gross receipts of the entire undertaking.

The great point of attack and the difficulties of defence in these cases, as in all others where the principle of receipts and expenses is adopted, is the tenant's capital. Now a water company has a great advantage over a gas company; it has statutory rights to collect its rates in advance, and it generally avails itself of this privilege. Obviously, therefore, an in-coming tenant of a water company would require less capital than an in-coming tenant of a gas company, for a gas company must manufacture its gas and deliver it to the consumer before it receives any revenue—with the small exception of that derived from the sale of the residual products—whilst, on the other hand, a water company receives its income prior to delivering its water to the consumer. This must have a considerable bearing upon the question of the capital necessary to carry on the undertaking.

The question of the dead mains or live mains is one of considerable importance, both to the parochial authorities and to the company whose assessment is under consideration. A gas or water company may have its works situated some distance away from where its produce is consumed, and the carrying mains are very often situated in parishes in which there are no receipts. Again, in other parishes there are mains which are directly tapped for the convenience of ratepayers and others which are only carrying gas or water, as the case may be, to some distant point of the district which they supply. The division between these two classes of mains must be accurately made, for whilst the directly productive mains are assessed upon the receipts and expenses principle, the unproductive or carrying mains are assessed upon a percentage of their structural cost. It would be impossible to lay down a rule that would be applicable in every case, indeed probably every case would vary according to the size of the district supplied by the company.

The gasholders and retorts necessary for the carrying on of a gas undertaking, and the reservoirs and pumping stations of a water company, are rateable at their rental value, and this value is derived from their structural cost. It has been sought to exempt gasholders and retorts as coming under the category of tenant's tools, but the fallacy of this contention was at once pointed out by the court.

In conclusion, the author may appropriately quote the words of one of our well-known judges, who aptly said, "It is impossible to be mathematically accurate, but it is my effort only to lay down a general rule, and the applying of it must be left, not only to the experience and acuteness, but also to the good sense, good faith and candour of the parties concerned, whose interest it will be found in the end to be best consulted by this mode of dealing."

DISCUSSION.

The CHAIRMAN moved a vote of thanks to Mr. Faraday for his paper. He said he thought that the judge to whom the author had referred must have been a good judge when he said that it was impossible to be mathematically accurate in matters such as that before the Meeting, for the paper had shown that the subject was decidedly intricate, and it was moreover one which, perhaps, some members of the profession had not had sufficient opportunity to consider. The old idea mentioned by the author, that a railway was available for any person who chose to use his own rolling stock upon it, was certainly interesting, and when it was remembered that a railway company only owned the surface of the ground over which their line passed, the question of rating would not appear to be rendered more simple. The author had spoken of a sum being set aside by a railway company for risks and casualties. He (the Chairman) did not know whether the author included depreciation in that amount, or whether that would come under the head of maintenance. There appeared to be many points which would very well lend themselves to discussion, and he was pleased to observe that there were present at the meeting many gentlemen whose opinions on the subject would be of very great value.

The vote of thanks was accorded unanimously.

The following communication from Mr. GEORGE E. ARNOLD was read, that gentleman being unable to attend the meeting.

"Mr. George E. Arnold begs to thank the author for his paper upon a subject about which the majority of engineers know very little. The subject is one in which many engineers are interested, by reason of their connection with the owners of the undertakings, or with municipalities or other local authorities. The great difficulty in dealing with the rateable value of large undertakings is the number of parishes interested, and the lack of unanimity amongst parochial authorities to work together, and so obtain a fair distribution of the rates the owners are under obligations to contribute. There is no doubt that in many cases the enormous cost of a rating appeal induces both owners and parochial authorities to be content with an assessment which, owing to diversion of trade or other circumstances, has become unfair. The author's remark as to its being 'a comparatively easy task for a properly constituted body to determine the rental value of the whole system' of an undertaking, suggests to the writer that a large proportion of unfair assessments might be adjusted if there was authority given to the Local Government Board to have a valuation made of large undertakings, at the request of a certain proportion of parishes interested, and at intervals of not less than ten years; the cost of making such valuation, and of any proceedings consequent upon it, to be borne proportionately by all the parishes according to the assessment in each. This would result in a proper division of the value, and the owners should welcome the new system because it would remove the trouble and anxiety of an appeal every five years in some part or other of their system. The assessments only to be altered in any parish by reason of new works and extensions made between valuations."

Mr. J. Patten Barber expressed his appreciation of the paper. The author had clearly shown the great difficulty that there would be in putting a mathematically correct value upon railway lines which went through several parishes. A large proportion of the terminal works of a railway was used for the traffic over the whole line, and it must be obvious that it would be an exceedingly difficult task to make an actual valuation of the undertaking in every parish through which the line passed. Of course it was manifestly incorrect to assume that the value of the land on which a railway company's line was laid was to be considered as though it was used for agricultural purposes, although it might have been agricultural land up to the time of the making of the railway. The value of the land was increased immediately after the railway was made. It might be contended that every parish in the kingdom through which a railway ran had some claim to a portion of the rates payable upon the undertaking in one particular parish, on account of certain works which were not used solely for the railway company's business in that parish but in connection with the whole of the traffic over their entire system; just as there might be terminal works, bridges and tunnels, used for the whole business of the railway company, and not merely for that portion of it which was carried out within the parish where such works and structures were situated. Hence the rateable value was most difficult to obtain.

It was not often that the works of a railway company or any public company fell into disuse, but the case of a tramway in the parish of Islington occurred to his mind. The line had been closed, and he supposed that the value of it was absolutely *nil.* Whether the rates were paid in respect of that tramway he was not in a position to say, but on the principle that the rates were to be based on the value of the property if let to a tenant, no rates could be demanded. There were difficulties in the assessment of other things besides the works of a railway company, as, for instance, with regard to the mains of a water company which did not serve the parish through which they ran. He thought the author had correctly indicated the only principle upon which such mains should be assessed, namely, that the prime cost should be ascertained, and a certain percentage paid upon the amount, and the rates levied upon that. It appeared to him that the local authorities were entirely dependent upon the accounts and returns issued by the railway companies in such a case, and of course that was hardly a satisfactory state of things. He was not in a position to say what he would suggest as the best means out of the difficulty.

Mr. WILLIAM EVE said he thought Mr. Barber was quite right as to the non-rateability of tramways if they were not used; or, at any rate, if they were put on the rate books of course they did not pay rates. There were many tramways in Liverpool which were not used at the present time, and which were not rated. If he rightly understood Mr. Barber's remarks with regard to terminal works and sidings, and their being distributed over the whole length of the line, he must venture to differ from him, and to say that in his (Mr. Eve's) opinion the parochial principle must be distinctly adhered to. Where sidings existed they must be rated. Mr. Barber had very wisely alluded to the very unsatisfactory necessity of accepting a company's returns. He did not think that as a rule a company got their returns out wrongly, but there were so many ways of dealing with the particular route which a passenger might take, and with season tickets and other matters, that any return from a railway, although perhaps mathematically correct, might be extremely unreliable with regard to those particular points.

The author alluded in his third paragraph to the wealthy company having a decided advantage over a poor parish. The wealthy company also had a very decided advantage over every ratepayer who paid rent. There was no getting out of a fixed rent paid for a house. A railway company was never rated up to what it ought to be rated, whereas in the case of a house there was a fixed rental, and the occupier had absolutely no relief from the rates. He (Mr. Eve) would emphasise the other evil to which the author alluded with regard to the wealthy company, namely, that, whereas the ratepayer was rated up to the hilt, that was very seldom the case with regard to a railway company. The author had said that at first sight the receipts and expenses afforded a wrong principle to go upon, but in a later part of the paper he said it was a right principle. There was exactly the same principle with regard to a farm. The only difference was that persons who valued a large quantity of land were able to look at the land and say what it would let for, but really the basis of what it would let for was simply what it would produce, and what were the expenses of producing crops, and what would the tenant want for his profit. The same process must be gone through in the mind of the valuer, whether he was valuing land or valuing a railway. He had to consider the productiveness of the land in the one case and the productiveness of the railway in the other.

He ventured to differ from a point stated by the author in a subsequent paragraph. The author's words were, "The constituents of a tenant's capital of a railway company would consist chiefly of the rolling stock, conveyances at the various termini, horses, &c., tenant's stores," and so on. But inasmuch as cartage rate receipts were not proper subjects for rating, therefore the value of the horses which conveyed the goods should not come into the tenant's capital. Horses ought to be excluded, because no portion of the receipts derived from carrying out that branch of work was included in the receipts of the company for rating purposes.

He was sorry to say that he had been a very great many years trying to convince the courts that 17½ per cent. was wrong, and he had hoped that he had nearly accomplished it in the case of Sir Peter Edlin; but he was sorry to say that Sir Peter's successors had adhered definitely to the 17½ per cent., so that, as far as London was concerned, the war which had been waged for so long would have to be begun over again. He had been hoping that during this quinquennial valuation they might have succeeded in getting the 17½ per cent. altered. Not only should deductions be made from the gross receipts to allow for the rent which the tenant would have to pay for the use of the stations, but, what was not unimportant nowadays in London, they had got to take the rates as well, and as those rates were very high in most parishes that was a very important point.

He wished to criticise an expression which occurred several times in the course of the paper, and that was the word "cost." The expression was a most dangerous one. He suggested that the word "value" should be substituted for "cost." A thing might cost anything, but when it came to be rated, attention must be confined entirely to the question of value, and must not be directed to the question of cost. "Cost" and "value" were synonymous terms only when the outlay had been judicious. Very often a railway company had to enlarge its station, and the work had to be done while the traffic was proceeding. That necessity often caused the cost to be from 20 to perhaps 50 per cent. more than it would be if the work was done under ordinary circumstances. That was a consideration to be borne in mind, and therefore he preferred the word "value" to the word "cost."

Mr. Faraday also alluded to a very important question which he (Mr. Eve) did not think had been quite settled at the present time, namely, the question of signals. Referring to signals, the author said, "They are only erected because of the stoppages which take place, and the many stations situated on the route of a great trunk line. The case, however, with regard to signals at a junction is different, as these are included in the valuation of the line." He (Mr. Eve) hoped that that point was not quite settled yet as to whether signals should be included in the line or should be rated in the parish in which they were situated. His own practice was always to treat them locally. Still it was an open question whether they should be rated in that way or not.

He was glad to see the author's remark with regard to maintenance and renewal of way. The author was quite right in saying that the expenses would not necessarily by any means be heavier in the same proportion where the traffic was heavy as where it was light. If a similar number of trains was run over every mile in the system, nothing could be easier than train mileage, but it was clear that much of the decay of a line was due to the atmosphere and not to the trains. Therefore maintenance did not always increase in proportion to the train miles. There were many constants in the process of decay whether trains passed over a line or not. He did not quite agree with the author's statement: "It follows, therefore, that in certain parishes railway companies may be in the possession of property which contributes nothing to the local rates, for although there is undoubted value to the present occupier, the question which really determines the assessment is, "What is the value of this property *per se* to a tenant if it were let?" He did not think that the decisions supported that conclusion. With regard to the last words in the same paragraph the highest authority which he could quote on that subject was the present Attorney-General, who was at one time one of the best advocates on the question of rating. He (Mr. Eve) had a case in which the Attorney-General was arbitrator, and he decided that where a non-paying line formed no physical connection with a paying line in the same parish it might be ignored; but if the physical connection existed, it must not be ignored. Whether the Attorney-General was right or not he could not say, but it happened that in that particular case there was a non-productive line and a very productive line. In the one case there was a physical connection with the main line, and in the other case there was no physical junction, and the Attorney-General said that in a parish where a junction existed the branch line must be put into hotchpotch, but where there was no physical connection it need not be. This view was stated some years ago, and, rightly or wrongly, he (Mr. Eve) had always followed that principle.

As to the statement in the first paragraph about canals, it was not quite accurate. Canals were formed under special powers, and a large proportion of them could only be rated upon the value of the adjoining land—not the value when the canal was constructed, which was the rule in some exceptional cases, such as fortifications and various things of that sort. With regard to a large number of canals, the Regent's Canal among them, the rating must be according to the value of the adjacent land, and as the land rose in value they might be rated higher, but they could not be rated according to their productive value.

He must take exception to the expressions "dead" and "unproductive" mains, as used in the paper. He preferred to speak of them as indirectly productive mains. The terms "dead" and "unproductive" were very largely adopted, but really a main which was called a dead main was just as useful and necessary to the undertaking as one that was tapped. In the case of the Gas Light and Coke Company there had been adopted a principle which he had suggested. Inasmuch as some of the very largest mains were tapped in the streets in which they occurred, he had been unable to find any basis which was absolutely sound on the principle of size. The matter did not depend entirely upon diameter. The principle which he suggested, and which was adopted, was to take as indirectly productive only those mains which went from station to station.

There was one remark which he wished to make on the observations contained in Mr. Arnold's communication. He suggested that a valuation should be made by the Local Government Board. He was very sorry to see that Mr. Dewey approved of that plan. He (Mr. Eve) had had his knuckles rapped very severely by his brother surveyors for advocating that it should be done in London by the London County Council. The surveyors said that such a proceeding would do away with a great deal of their business; and what would happen if a similar course was followed all over the country was something too awful to contemplate. He thought that it was reasonable that in London, where many of the rates were charged over the whole area, there should be some system by which the valuation should be made by the London County Council or by some other authority, and that the whole should be rated and divided. He supported that plan in the Conference which took place on the subject. But to apply it to the whole of the country, where the same rates were not applicable, would be, it seemed to him, an unnecessary interference with a very valuable and useful body of men.

Mr. G. Cooke agreed with Mr. Eve's remarks about the special acts relating to certain canals which exempted them from the general law of rating to which railway companies were subject. For instance, the Grand Junction Canal at Paddington was simply rated at the value of the adjoining land, and not as a concern earning so much money. Mr. Faraday had said that the question was to find the value of the hereditament to a hypothetical tenant for a similar occupancy. The word "similar" did not seem to be a very happy one. What was meant was an identical occupation, because they had to consider not only possible tenants but the actual tenant in possession. This was laid down by the Court of Appeal in the case of the School Board against the Parish of Shoreditch. With regard to the data as to value to be obtained from the printed reports, so far as the gross receipts were obtained one could only get the average earnings of a train over the whole system. That might not be of much use, for one might be valuing in London and the system might extend several hundred miles away into the country. Some parts of a line might not be worth anything. The surveyor must use his own judgment. The difficulty was increased when a railway company mixed up its boat receipts with its train receipts, as the London and North Western did. But it might be taken as a rough guess that boat traffic was not remunerative, and did not do more than pay its way. What Mr. Faraday spoke of as the rental value of the dead or indirect works was a very difficult thing to get at. It was generally more or less assumed, as it was impossible to arrive at anything like an absolutely correct conclusion. A station might be of one value for poor rate purposes, and of another value for general district rate purposes; as stations consisted partly of what in a legal sense is "buildings" and partly of "line." With regard to the term "dead works" which had been used in the paper, he (Mr. Cooke) preferred the expression "indirect works." The cost of a station had really very little to do with its value for rating purposes. Its present structural value, and the use to which it was put, had to be taken into account. In the case of lines not having any rateable value, it was the custom to agree to a rateable value of something like 20*l.* or 25*l.* a mile, this amount being reckoned on the acreage which the lines occupied.

In the comparison between a water company and a gas company, he thought the position of the water company was infinitely stronger than that of the gas company. The inhabitants must have water, and they were bound to take it, but they were not bound to take gas. And the powers of a water company were much greater than those of a gas company. But the making up of the tenant's capital in the case of a water company was a difficult thing. It might almost be said that they did not want any capital at all. With regard to the 1890 quinquennial valuation of the gas companies in London, the method adopted by the court in the Gas Light and Coke Company's appeal was to take the mains called pumping or high pressure mains as indirect mains. Of course it did not matter much to the company so long as one principle was adopted. There was great difficulty in laying down a principle, as previously it had been the custom to take everything over twelve inches as "indirect." With regard to the 17½ per cent., so far as London was concerned, it was, he believed, fixed, as the London Court of Quarter Sessions had recently held that they did not see their way to depart from that allowance. In the country 15 per cent., and sometimes less, was frequently adopted.

Mr. Wm. F. Dewey said that as one who had been associated with rating and assessment matters ever since the Act of 1869, he might be able to throw out some suggestions which would be of interest. Mr. Faraday was to be congratulated upon his very able exposition of the law and practice of rating. His own experience led him to doubt whether the figures relating to the total receipts of an undertaking and to tenant's capital were ever completely shown for assessment purposes. He did not intend to imply that railway companies falsified their figures, but anyone who had had experience of the books of large companies knew that figures could be looked at from different points of view, and that things could be concealed. The rating experts of the companies could hardly be blamed, but, since such persons had the control of the figures which they supplied, who could wonder at the statement which Mr. Eve had made and which he (Mr. Dewey) endorsed, namely, that not one of those large undertakings which contributed so largely to the rates of the Metropolis and of the kingdom was rated nearly up to its proper value.

He wished to confirm the remarks which had been made with reference to the question of rating canals. He had been wondering whether he was up to date as regarded the law on that subject, but he was under the impression that nearly all the canals of the kingdom were rated under private Acts simply as agricultural land. Some time ago he attended the Local Government Board as one of a deputation in connection with a movement which was then on foot for getting the law as to the rating of canals altered, but he believed that no alteration had been made.

Mr. Faraday had very properly called attention to the question of interest upon the tenant's capital, and he had emphasised it as the most difficult matter in connection with arriving at the correct value of a company's undertaking. First it was difficult to ascertain the amount of the capital itself, and then it was even more difficult to settle the proper interest upon it. He fully endorsed what Mr. Faraday had said with regard to the absurdity of allowing 5 per cent. as interest on capital. He thought not only that the 5 per cent. should be lowered, but that it was also wrong that the trade profits should be allowed at 10 per cent. Further, there was in very few cases a shadow of an excuse for allowing 2½ per cent. for depreciation. As a rule, railway companies maintained their lines under the heading of maintenance up to date from day to day. There was no depreciation at the end of a period of time, and he would go so far as to say with regard to most of those undertakings there was no ground for allowing any depreciation whatever. But he wanted to emphasise the question—How was it that at the present time the 17½ per cent. was allowed to go almost without question? Unfortunately none of the parishes were disposed to press the matter home. What was wanted was to bring into court the evidence of large financiers and traders to show what really was the interest derivable from capital invested in such businesses as those, and also what would be a fair return for what might be called trading undertakings. If parishes combined they would, he thought, compel the courts to decide against the allowance of such an absurd interest for tenant's capital as 17½ per cent. He took it that it was to the interest of the ratepayers that large trading concerns should be rated up to their proper rateable value; but that result would never be brought about under the present parochial system of rating.

A large railway system, such as the London and North-Western or the Great Northern, passed through perhaps a hundred parishes. How did it escape its proper contribution to the rates of the country? It did so by treating the parishes as the bundle of sticks in the fable, and fighting them separately. If the parishes would unite they would perhaps obtain a proper valuation.

In the early part of the paper, Mr. Faraday had suggested what was the keynote of his (Mr. Dewey's) remarks. It was not only easy for a central body to determine the rental value of a portion of a great length of line, but it would be equally easy for a properly constituted body to determine the whole value of the North-Western Railway system, and to apportion the receipts, and train mileage and expenditure, and consequently the rateable value, to each parish. Such a properly constituted body was wanted.

He was struck by the suggestion in Mr. Arnold's communication that such a department as the Local Government Board could carry out the valuation. He ventured to say that if the rating of the lines was carried out in that method the rating would be increased to the advantage of small parishes. He believed that in the London parishes there was an approximation to fair rating, but small parishes which failed to employ experts must be at the mercy of the companies. His conviction was that the only proper solution of the company question was an assessment by some central body in London. He believed that the London County Council would be the proper agency to carry it out. If parishes were alive to their own interest they would be in favour of the value being assessed in that way, and the poor parishes would be thus relieved of a somewhat heavy burden.

Mr. W. F. Hart said he was a representative of the poor water companies, and he saw in the meeting several representatives of rating authorities who were ready to swallow him up if they caught him tripping, consequently he did not wish to give them the opportunity. The author of the paper spoke of the obvious advantage which a water company had as compared with a gas company, owing to the fact that the former had a statutory right to collect the rates in advance. That right might exist in law but not in practice. It was, however, a great disadvantage to the water companies when they came to be rated, because there was so much less to be deducted for tenant's capital, and that meant that the water company was rated all the more. He knew that the companies were dissatisfied, on account of their being attacked by twenty or thirty different rating authorities representing different parishes. He believed that if the companies could be assessed by one body for the whole of an undertaking, and the amount apportioned among the different parishes interested, it would be much more satisfactory to all parties. A suggestion on such a matter as that would, no doubt, receive the attention of the Royal Commission on Local Taxation which was now sitting, and it was worth while to consider what suggestions could be made with regard to an alteration.

Mr. Price-Williams said the author had remarked that there was a great difference of opinion with regard to the question of the maintenance and renewal of the permanent way of a railway. He believed the view of all permanent way engineers, and indeed of the profession generally, was that maintenance and renewal were synonymous terms and that it was impossible to distinguish between them. It was the same with rolling stock. From the moment the wheel of a locomotive revolved to the day it was sent to the scrap heap there was a continual wear and tear going on requiring renewal.

One of the speakers had referred to the effect of the elements in the wear of the rails, and said that the mileage run was not the only question involved. No doubt rust had something to do with the matter, but he thought that it must be accepted that the measure of the life of a rail was in fact the amount of traffic, the speed, and the tonnage passing over it. It should also be remembered that with very heavy mineral traffic there was a large mileage which did not figure at all as train mileage, namely, the empty-train mileage back. As to the depreciation of the stock, a previous speaker said he did not consider any allowance should be made for it. He agreed with that view to some extent, for it was quite evident that if a railway had a large number of locomotives, say a thousand, they could never have the whole of that stock except in a partially depreciated condition. There was always present, in fact, a certain amount of depreciation, which was termed "normal depreciation," which he had estimated at about 33 per cent. That was to say, in any rolling stock, however well maintained, there must always necessarily be that amount of depreciation which could never be overtaken.

His friend the late Mr. Kinnear Clark went even further, and considered that this depreciation increased at an arithmetical instead of a geometrical rate. That question had come prominently before him (Mr. Price-Williams) at the time he was engaged in valuing the Irish railways, and the Royal Commissioners fully recognised that allowance must be made for it. The railways, however, were none the less valuable, and efficient money-earning undertakings on that account, as even should the stock be in a brand new state it would not be able to earn a penny more. Another speaker said that, owing to the insufficient returns made by the railway companies, he had been obliged to take the entire receipts of a line as the gauge of the value of the traffic in any particular parish. A little observation would show that these railway returns might still be made to afford the means of much more approximately gauging the value of the traffic over a particular portion of it. The working time tables, for instance, afforded the means of very approximately arriving at the number of train miles in any particular parish. This subject was a very wide and interesting one. The interests of the railway companies themselves were, he considered, largely concerned in affording more detailed information in their published reports. The growth of the item of "rates and taxes" of the London and North-Western Railway during the last ten years had greatly surprised him, as it had been much more rapid than the growth of either the traffic or the train mileage in that period. He maintained before that it would be much better for the railway companies to make a clean breast of it, and furnish the public with more details in their annual reports than was furnished at present. One point which had a very important bearing upon the question of rating was the actual cost of conveyance as distinguished from terminal charges. Many points connected with these rating questions, which were now so difficult and complicated, might, with the aid of the railway companies, be much more easily and satisfactorily dealt with, and upon sound and reliable principles, and that most complicated and distracting question in regard to the hypothetical tenant and landlord would then be entirely got rid of.

Mr. H. G. ASSITER said it was a very great privilege to have been present to hear Mr. Faraday's paper and the discussion upon it. Mr. Eve had suggested that signals should be valued separately, and rated similarly to stations in the parish in which they were situated, but he did not quite follow the whole of Mr. Eve's theory as to that. It seemed to him that signals were quite as necessary for the working of a line as the actual roads themselves, and that therefore it would be more equitable to include them with the valuation of the line, and certainly it would be so where a junction existed where signals would be necessary whether there was a station or not. With regard to the giving of information, it was hardly to be expected that a railway or other large company would afford great facilities for assessment by submitting its accounts in such a way as to increase the rateable value of its property. With regard to boat traffic, did Mr. Cooke suggest that it should be treated in a similar manner to an unproductive branch—that is, as a feeder—and valued on the same footing? The last speaker had said that the rates of the London and North-Western Railway had increased during the last ten years out of proportion to their receipts. Might it not be possible that that only afforded a proof of the fact that the company's undertaking was inadequately rated in the past?

Mr. W. G. COOKE said that the principle was that the land itself was the rateable hereditament, and that the vessel going over the water could not be held to be rateable; nor could the sea be held to be rateable. But inasmuch as the railway and boat fares were combined, the railway company apportioned the amount, and included in their statement of gross receipts the part due to the railway journey.

Mr. FARADAY said he was very much indebted to the speakers for the useful and interesting discussion which had taken place. He had not expected to have so many rating experts present. He thought he had been a little misunderstood as to his advocacy of a properly constituted body for the purpose of rating a large railway undertaking. It had never been his idea that the body itself should do it. What he meant was that there should be a properly constituted court consisting, for instance, of three barristers and two surveyors. If such a tribunal existed, they would be able to get an equitable decision which they never had now. Going into court at the present time was like putting money on a horse. In nine cases out of ten the judges did not know anything about the subject at all. With regard to certain signals along the line of way, undoubtedly they were erected for the use of the company. In London, for instance, the stations would be perhaps a mile apart, and the traffic would be very congested and the trains stopped between the stations. Consequently signals were required for the working of the line, and undoubtedly those signals ought to be rated in the parishes in which they were situated. He did not think that the same principle would apply to the signals at a junction. As to canals, he was perfectly aware that most of them had special Acts in which it was provided that the rating should be done in a certain way, but he was not dealing with such cases in his paper. He was dealing merely with the principle, and there were canals which had not any clauses in their Acts dealing with the rating question. Consequently the principle was almost the same as in the case of a railway company. With regard to the Gas Light and Coke Company's appeal of 1890, he went on to state that the company brought into court plans wherein they marked certain mains blue, and those were taken as indirectly productive mains. He (Mr. Faraday) thought that he was right in saying that no mains were coloured blue which were less than 24 inches in diameter.

Mr. Eve said that that might be the case, but there were many of a larger diameter which were not included. That was the point.

Mr. Faraday said that with regard to the accounts of the companies he had no objection to them because they were issued for the benefit of the shareholders, but what he objected to was that an expert on the other side would often say that the receipts, in London, for instance, were not up to the average. With regard to the term "dead works," he should be perfectly willing to substitute the word "unproductive" for "dead," but he did not think that the difference mattered, because the expression "dead works" was found in Balfour Browne and Castle, and the phrase "dead works" was used by others also. He did not think that he had done very wrong in using it. With regard to trade profit, Mr. Dewey mentioned 10 per cent. He (Mr. Faraday) believed that the London and North-Western paid some 7 or 8 per cent. dividend. The capital upon which they paid that was enormous, but he should expect that if it was on a reasonable capital it would probably be found that it might exceed 10 per cent., and perhaps that was a point which had better be left alone.

He agreed with the remark that parishes which did not employ experts generally came to the ground. Mr. Price-Williams had said that he knew certain parishes where there was over-rating. He (Mr. Faraday) could only suggest that there should be an appeal in such cases. He was sure the North-Western had sufficient money for the purpose. Mr. Price-Williams further said that he noticed in the accounts that the rates and taxes had increased. That might be the case, but he (Mr. Faraday) did not think that that was any fault of the surveyors. He did not think that Mr. Price-Williams would find that the rateable value had very much increased in proportion. Rates and taxes had increased owing to the enormous amount now spent by local bodies, and of course that came upon the rateable value.

Mr. Price-Williams said that his object was to show that the item of rates and taxes had increased much more rapidly than the expenses, or the receipts, or the train mileage. That struck him as being exceptionally high, and not merely during a single year, but it showed a continuous growth which was much greater in fact than the growth of the traffic.

Mr. Faraday said that was just what he had been labouring to show. The rates and taxes themselves, that is, the amount of money paid, might have increased out of proportion, but he did not think that that could be put down to anything except the increased spending of the local authorities. Consequently the rate in the £ had been raised very much. That was the case in his own parish, and in Hackney, where they had reached 8*s.* to 9*s.* in the £, whereas ten or fifteen years ago they were very much less. But the rateable value had not increased much.

May 3rd, 1897.

GEORGE MAXWELL LAWFORD, President,
in the Chair.

AUTOMATIC GAS STATION GOVERNORS.

By Henry O'Connor, Vice-President.

Before describing minutely the more recent description of gas governors in use, it may be well in a society like ours, composed as it is of members of all the various branches of the profession, to describe succinctly the duty which the gas governor is called upon to perform in the ordinary way in a gasworks. Those who are members of the gas engineering profession will perhaps pardon the elementary nature of the few remarks which follow.

It is not apparently known who was the first to invent the form of governor commonly in use. Clegg, the inventor of the wet meter, however, patented a form of gas governor in 1815. The fact that this apparatus has remained in practically the same form since the earliest days of gas lighting, clearly shows it to have been an invention of the most complete nature, which should have been a feather in the cap of the engineer who designed it. It was quickly found that when gas was stored in the gasholder or gasometer and allowed to flow directly therefrom into the town, the varying weight of the gasholders at different heights, due to their partial immersion in water and the consequent difference between the weight and specific gravity of the iron of which they were composed, caused a considerable difference in the pressure thrown upon the mains in the town or district supplied. Again, the pressure required during the day, when little or no gas was in use, was only small, but without a governor it was impossible to alter the pressure from that thrown by the gasholder, except by means of the outlet valve, which might have been partially closed, and thus only allowed a small quantity of gas to pass. But in this case had a sudden demand for gas have taken place, the valve, only allowing a small quantity of gas to pass, would have prevented the extra quantity going out when required, and thus only a reduced supply would have been available. To remedy this defect the governor was invented, and is required, as ordinarily constructed, to maintain automatically at the outlet of the works a constant pressure upon the outgoing gas, whatever the variations of pressure may be in the inside of the works or outside, resulting from the lighting or extinction of burners upon the system of mains. These variations of pressure actuate the movable cone or valve, and cause the apparatus to deliver the gas proportionally to the needs of consumption.

Again, if we consider the loss in the main, there is a considerable advantage in reducing the pressure to a minimum, because whenever the pressure in the mains is greater than is strictly necessary for the requirements of the consumers, there is loss to the gas supplier. It has been said that where the leaks occur in the ground and through cracks in the mains, the loss does not increase as the square root of the pressure, as is the case with a leak from a round hole in the open, but directly as the pressure. When the pressure upon the outlet side falls owing to an increased consumption, the valve is opened for just so long and to such an extent as will restore the pressure to that at which the governor is set. Fig. 1 is a sectional drawing of such a governor, wherein the gas enters at D and passes around the cone C, through the hole in the seat, and away by the outlet at E.

The weight of the bell of the governor is counterbalanced, either by weights pendant from a chain passing over a wheel, or by means of floats in the bottom of the bell immersed in water, or by a combination of the two methods. The bell, therefore, being in equilibrium, the pressure of the gas has a natural tendency to cause the bell to rise, and weights have therefore to be either put upon the bell, or taken off the counterbalance weights, to again bring the bell into equilibrium; the amount of weight regulating the pressure of the gas necessary to effect this, and thus regulating the pressure at which the gas shall pass away into the town mains. The calculation for the amount of weight necessary for ensuring the desired pressure is very simple, yet the author has found many gas engineers who have not taken the trouble to inquire sufficiently into the question to thoroughly understand the laws governing it.

In the first place, the pressure of the gas is always spoken of as so many inches of water. Now, the weight of water is such that a column of 27·63 inches height is equal to a pressure of 1 lb. per square inch; therefore the area of the top of the bell in square inches divided by 27·63 equals the number of pounds weight necessary for 1 inch pressure. Let us suppose that it is desired to know the weight necessary to be placed upon a governor with a bell 18¾ inches diameter to cause an increase or decrease of 1 inch of pressure. We shall find that the area is roughly 2763 square inches, which divided by 27·63 gives us 10 lbs. as the required weight, or, in other words, 10 lbs. will cause a pressure upon the bell in the opposite direction to the pressure of gas, and to exactly the same amount as a pressure of 1 inch of water upon the bell top.

Another method of arriving at the desired end is to find the area in square inches of the bell top and multiply this by the weight of 1 cubic inch of water, which is ·0361 lb. This will give the weight of a body of water covering the top of the bell and one inch deep. This will equal the weight necessary for 1 inch water pressure, and any other pressure can be determined by direct proportion, that is to say, $\frac{1}{10}$ inch pressure will only require one-tenth of the weight so found, while 2 inch pressure will require double the weight, and so on. These are very simple rules, but they form the foundation upon which all the details of governors and many other pieces of gas apparatus are constructed.

But to return to the description of the ordinary gas governor. The gas, after it has passed the cone, is at liberty to press against the top of the bell, and it will then raise it and with it the cone or valve which is fixed to it by a chain or rod, at the same time reducing the space between the cone valve and its seat in direct proportion with the rise and fall of the bell. It is on this account that the cone is made of a parabolic curve instead of a straight cone, the parabolic shape being the result of the calculation of the necessary size of the cone at different points of its travel, to ensure an even and exact reduction of the area of the gas passage way between the top and the bottom of the travel of the cone. It will be easily seen that if the total diameter of the opening be 12 inches, the reduction of 1 inch in diameter, from 12 inches to 11 inches diameter, will cause a greater reduction of area than when the reduction is made from, say, 6 inches to 5 inches diameter. If, therefore, it is desired to divide the total height of a cone of, say, 18 inches depth so that at each 1½ inch from the bottom the sectional area is reduced by one-twelfth, it will be found that the necessary diameters are 12 inches, 11·48, 10·99, 10·4, 9·8, 9·17, 8·5, 7·76, 6·92, 6·0, 4·9, 3·45, 0, and these set out at the correct distances apart will form a parabolic curve as above described. The author has here a model to illustrate this, which consists of discs of cardboard of the diameters above mentioned fixed upon a string at distances of 1½ inch apart, and a student may amuse himself by calculating the areas of each disc, when he will see that each disc is the same number of square inches less in area than the one preceding it. By opening the discs to their correct distances apart, it will be noticed that their edges form points in a parabolic curve, and by dividing still further we can obtain, if necessary, more points in this curve, which will enable us to set it out with great exactness.

When the gas in the mains is being consumed rapidly, the pressure tends to fall, when the counterbalancing of the bell by the pressure of gas is reduced, with a consequent fall of the bell and an opening of the passage way for the gas, which permits a greater volume to pass until the balance of pressure is once more restored; and this goes on continuously, the cone valve opening and closing as required.

The governor thus described is, as before stated, substantially the same as was designed in the earliest days of gas manufacture and supply, and since that time various slight modifications of this piece of apparatus have been devised to overcome certain small defects which it has been found to contain. In the first place, the pressure of the incoming gas upon the under side of the cone caused a variation in the outgoing quantity when anything occurred to alter this inlet pressure. This defect was overcome in different ways. One was by making the gas passage way in two with separate cones, both pending from the same chain one above the other; but the gas, instead of passing as in Fig. 1 on the under side of the cone, is made to pass so that the upper cone has the pressure upon its under side and the lower cone is pressed upon its upper side, thus causing the cones to be in equilibrium, and removing the possibility of variation of outlet pressure due to the varying weights of gasholders, &c. (See Fig. 2.)

Another method of accomplishing this end is to make the gas pass downwards past the cone, and at the same time press upwards against such portion of the top of the bell as will equal the area of the bottom of the cone; an inner chamber or bell being made, to the under side of which the inlet pressure is brought, the remainder of the bell being subject in the usual way to the outlet pressure of the gas. (See Fig. 3.)

One thing in this pattern governor, which is usually taken advantage of, is that the connection from the gas mains to the bell need only be very small, so that should the bell by any means get canted and leak, the quantity of gas lost will be comparatively small. The connections, both on inlet and outlet sides of the governor, are usually only wrought-iron tube of about $\frac{3}{4}$ inch diameter, while the old pattern governor was open to the full size of the connections should the bell get displaced.

Now in all these forms of governor, the pressure of the gas at the outlet to the town mains is decided upon by the engineer, and weights are either put on or taken off as the pressure is required to be greater or less. But should these weights be put on or removed too suddenly, the rapid change in pressure may cause the whole of the lights in a town to be extinguished, and to obviate this trouble several methods have been suggested and tried with success.

One of these, shown at Fig. 4, is the invention of Mr. W. Foulis, and differs very considerably from the usual type of governor, inasmuch as the bell itself forms the cone or valve, and the whole being contained in a cast-iron case, the usual method of placing weights upon the bell cannot be adopted. A second bell is therefore placed in a separate tank, which may, if desired, be placed half-a-mile away, and is connected to the under side of the bell of the governor by a wrought-iron tube, so that the pressure on the under side of the governor bell and that on the bell in the tank are the same. Consequently any loading placed upon one bell, and causing increased pressure upon it, is at once communicated through the tube to the other bell. In this governor this pressure is used to counteract the pressure of the gas upon the upper side of the coned bell, and thus the valve is kept in equilibrium. But, further, to keep the coned bell from responding instantaneously to the pressure on the under side, a plunger is connected to it in such a way that a liquid, usually glycerine, has to pass from the inside of the cylinders to the outside, either through the space around the plunger, or through a very small hole provided in the upper end of the cylinder. Acting somewhat in the same way as the familiar anti-doorslammer, this forms a preventive to the too rapid opening or closing of the valve, and would have entirely prevented a recent trouble in the North of Ireland, where the fainting of the workman who was loading the governor bell caused him to fall upon the bell, thus extinguishing the lights of the town. If the governor now under notice had been in use, the only effect would have been that the lights would have probably flared up rather too high, owing to an increase of pressure, but it would have been so gradual as to have been hardly noticeable, while at the same time this governor is so sensitive that the mere weight of a coin will cause a difference in the pressure thrown by it. These actions of the plunger and cylinder have recently been adopted for a similar purpose on a governor for regulating the supply of steam to the engine driving the exhauster of a gasworks, so that the steam is automatically partially shut off when the supply of gas from the retort is somewhat reduced, the plunger system preventing the steam from being entirely closed off if by any means the pressure should suddenly be lowered.

Another method of loading to prevent sudden and jerky changes of pressure has been employed, and this has been by the use of water as the loading agent. This water can be gradually run in so that the increase of pressure is likewise gradual. The removal of this water is effected by means of syphons, which can be set to work at any speed by means of taps which can be opened to just such an extent as is found most suitable.

Another method of obtaining an equilibrium gas governor is to have the two cones, one inverted, fixed pendant one from each end of a balanced cross bar, as shown in Fig. 5, which is the patent of Messrs. Hawkyard and Braddock. The two cones balance themselves, and act in opposite directions in combination with the bell, which is fixed directly over one of the cones, the connection to the other one being carried down through a sealing bell only, which is, of course, of small diameter. The weights are placed upon the larger or governing bell, so that should the pressure of gas on the outlet side be increased by any cause, such as diminished consumption, the large bell rises proportionately, and closes both cones by raising the one pendant from it and lowering the one pendant from the opposite end of the cross bar. If, however, the pressure decreases on the outlet, and the bell falls and makes the space around the cones increase, it increases the quantity of gas passing to the outlet side, and thus raises the pressure and the bell. The connections from the cross bar to the bell can be made adjustable so that both cones can be opened and closed simultaneously. One peculiarity of this governor is that either end can be made the inlet, the only difference being that the pipe leading from the outlet side to the governing bell must be fixed so that it obtains its pressure from the issuing side of the apparatus. There is also no float required, and the balancing weights are of smaller size than is necessary with the ordinary pattern governors.

A distinct departure from the ordinary pattern governor is made in one in which the suspended parabolic cone for opening and shutting the issuing orifice for the gas is entirely dispensed with and a balanced throttle valve is substituted, which is made to open and close by means of levers or radius arms placed inside the valve chamber upon the disc. The advantage of this pattern governor is that the bell need only be of small area. (See Fig. 6, which is the invention of Mr. C. Hunt.) It would appear, however, to the author, that this system has the objection that the opening for the passage of the gas does not increase in area strictly in accordance with the rise and fall of the pressure and in consequence of the bell, hence the same effect is caused as if the cone of an ordinary governor were made truly conical instead of parabolic.

Of all the various patterns suggested for the valve other than the usual parabolic curve it will be impossible to treat, as there are a large number only differing from each other in some slight degree. One is shown in diagram No. 7, in which the conical portion is restricted to the upper part only of the valve, the lower portion passing through a space fitting it fairly closely. This arrangement, which is the invention of Mr. J. Milne, removes the pressure from causing the bell to rise, as any increase in inlet pressure rather causes a falling of the cone than otherwise, and, thus allowing an extra quantity of gas to pass to the outlet side, immediately raises the valve, owing to the excess of pressure.

A considerable number of valves are made of a conical chamber somewhat like the one last mentioned, but with holes cut in the sides through which the gas has to pass, the height of this chamber above the seat regulating the quantity of gas passed. The exact shape and area of these holes are determined by calculation, so that the rate of increase of area in the gas passage is exactly in proportion to the fall of the bell.

To avoid the heavy weight of the bell causing excessive friction upon the wheels over which the chain passes to the counterbalance weights, annular air chambers are sometimes placed around the bell of the governor, which give the latter a buoyance. These can be made of such size as to entirely dispense with the need of any counterbalance weights at all, and in these governors the pressures are increased by adding weights to the crown of the bell instead of removing them from the counterbalance weights in the usual way, the contents of the air chambers being, of course, sufficient to give enough buoyance to the bell to keep it high enough, when no weights are on, so that the pendant cone is drawn up until the hole in which it works is entirely closed even when no pressure of gas is presented to the under side of the bell. Combinations of the two systems have also been adopted when the diameter of the governor has been preferred to be of such size as to prevent the use of an air chamber of sufficient capacity to alone effect the desired pressure.

Easy working of the bell is necessary, and ball bearings have been employed to ensure this where considerable weight is required to counterbalance the bell. A large bell ensures a considerable difference in the pressure exerted to raise and lower the bell when only a slight difference of gas pressure is apparent, but at the same time the extra weight of the bell and this larger pressure require a greater amount of counterbalance weight, both of which necessitate a greater effort to overcome the *vis inertiæ.* Gas managers are very loth to recognise that it is not necessary to have the valve the full area of the pipes conveying the gas to and from a governor. The rate of passage of gas past a cone and through a circular opening has, perhaps, never been accurately worked out, but the author feels sure it would surprise many who have held strong opinions on the subject. Probably the shape of the cone causes the gas to flow easily through the aperture, but more probably the principal cause is the very short distance which the gas has to traverse through the smaller area. It is well known to many that when small mains are in use and it is desired to make a connection for a side street of, perhaps, only a little smaller diameter than the original main, it is frequently the practice to tap a hole only some three-quarters the diameter of the connection proper, and to place a short length of tubing of the smaller size, and then, with a reducing socket, increase to the larger dimensions. It has been found over and over again that this has no effect upon the output of the connection, the short distance of travel through the smaller diameter main amply compensating for the restricted area.

The pressure at any point of the district is equal to the pressure at the works, less that lost through leakage and that consumed between that point and the works. Therefore, if it is required to maintain a uniform pressure at any point, it is necessary to make the outlet pressure at the works follow the same variation as the loss of pressure due to leakage and consumption. Pressure is also lost through friction against sides of mains.

With the ordinary governor it is necessary to load it earlier and to a greater extent, and again reduce it at a later hour than is required by the consumption, owing to the need that the pressure must not be allowed to fall lower than has previously been found necessary. It will be noticed in all pressure registers that the line rises as soon as the weights are put on, and then rapidly falls until the next weight is placed upon the belt. This is shown by a reference to the gas pressure register, Diagram 1.

The variations in such a climate as ours necessarily alter considerably the hours at which it is necessary to illuminate the houses and shops of our towns, and, in consequence, the time of day when the increased consumption renders an increase of pressure necessary. No gas engineer can therefore decide absolutely beforehand at what hour the weights are really required to be placed upon the governor bell, and must, therefore, depend largely upon the good sense and carefulness of the attendant in whose charge the governor is placed. Provided this attendant is competent and fulfils his duty conscientiously, a great deal has been done towards assuring a fairly even pressure throughout the district. But in many places the works are placed at a considerable distance from the town proper and the centre of consumption, and it may be still light at the works while a dark fog is beginning to spread over the town, and the pressure is really wanted to be augmented. The attendant, however, knows nothing of this and will not alter the pressure until the usual hour, and then it will be put on in such a way as to cause a slight but quite perceptible jump at the lights adjacent to the works.

It has been proposed, and such an apparatus is in use, that the pressure should be put on and taken off by means of water loading through taps which are opened and shut by means of clockwork. This will certainly carry out the desire of the gas manager so far as putting on and taking off the pressure at the pre-arranged hour, but it takes no notice of dull days and consequently the earlier lighting up of the burners in the town. Everyone knows the difficulty encountered when it is required to suddenly and only occasionally attend to a piece of apparatus which in general attends to itself, and it can easily be seen that it could often be the case that the necessary pressure, when required at an earlier hour than usual, would not be put upon the district. Again, the delicacy and complication of the clockwork renders it somewhat doubtful that this is a satisfactory solution of the question.

The area of the trunk mains is often very much too small for the consumption of gas which has to pass through them, rendering a larger pressure necessary to force the required quantity through them. This has a distinct effect upon the pressure at which the gas must be supplied at the works, and in designing any automatic system this must be taken into consideration.

There is no doubt that what is required is an equal and regular pressure at the service pipes of all the consumers in the district, and if this cannot be obtained in its entirety, a near approach to it will be better than the present system of giving a high pressure at the works to enable the consumer at a distance to obtain a fair pressure, even when the demand for gas nearer the works is very large. This is well so long as the demand remains very large, but if it diminishes, the pressure, both at the consumer's premises at a distance, and at those nearer the works to a greater extent, becomes excessive. This question, which some time back appeared inevitable, was allowed to lie neglected, as no way out seemed possible unless a man with brains were kept in attendance to alter the pressure as the demand increased or diminished.

Again, in days gone by, the demand during the day was very small, and the gas manager could safely lower the day pressure to $\frac{10}{10}$ without much fear of any complaints that some customers could get no gas. Consumers now-a-days use considerably more gas during the day for sundry purposes, such as for cooking-stoves and gas engines, both of which require a fair amount of pressure for satisfactory working, and consumers are more exacting in their demands, and the question of economically satisfying those demands is acquiring greater importance day by day. Excessive pressure in the street mains increases the leakage, but insufficient pressure not only calls down complaints, but reduces the consumption. Vague and irregular pressures are not only the worst but also the commonest of distribution evils, and though the gas manager does not alway hear them, they exercise a bad effect on the bulk of the consumers. One of the principal causes of these irregular pressures is the custom of putting on a regular pressure at the works between certain hours of the evening, when presumably gas is most required, but the quantity required is continually varying, as anyone who has watched the rate of travel of a station meter will readily own. Again, the custom is very usual of giving the same maximum pressure for a certain period during the summer quarter as is given during the winter quarter, while the consumption per unit of time is far less than in the latter case.

The dream of the gas manager is probably the supply to each consumer throughout his district of a gas of equal illuminating power to that sent out from the gasworks, and delivered at the consumers' burners at an equal pressure throughout the district which his mains traverse. That this is likely to remain in its entirety but a dream is, the author fears, but too probable. The difference of temperature and barometrical pressure, varying so much as it does throughout the districts supplied in many cases from a single works, where the levels may vary considerably, will alone account for a considerable variation in the pressure, while the friction in the mains will account for a further alteration. Much has been done by Peebles, Sugg and others, in supplying, for the use of the consumer, small governors or regulators, which enable him to reduce the pressure at which the gas is consumed at the burner to the limits within which it has been found most economical to use the gas. But, alas! the consumer is not easily trained to recognise the advantages to be thus obtained, and is very liable to think more of the initial cost of these regulators than of the undoubted saving which is obtainable when they are used, while the burner hawker, with his plausible tales and cheap burners, is ever among the customers and pouring into their ears the very doubtful advantages of his wares. Unfortunately for the gas manager the consumer is accustomed to blame the gas company for every deficiency in light which he detects in his own burner, and is very chary of accepting any advice from a man whom he wrongly considers to be his enemy, namely, the gas manager. If he can only be brought to understand that it is to the gas manager's interest for him to burn his gas to the best advantage and to be satisfied with the light he is obtaining, the gas manager's life would indeed be a happy one. But as this is not the case it behoves the gas manager to do all in his power to supply to the consumer the gas at such a pressure as will suit the majority of the burners used throughout the country. Hence the great necessity of adopting any form of governor in the works which will so regulate the supply that the pressures at any part of the town are uniform, not only from day to day, but also at the same hour on each day. This can only be done when the works governor is controlled automatically in such a way that the pressure is in accordance with the size of mains and the output at the moment of gas.

Such an apparatus has recently been invented by Mr. James Milne and the author, who proposes to describe some of the various methods by which this automatic loading and regulating of the bell may be carried out. Perhaps the more easily understood arrangement is that in which a quantity of water is made to pass by automatically acting syphons into a chamber attached to the bell, in such amounts as will cause the weight upon the bell and the necessary pressure of gas on the outlet of the governor required to counteract this loading, to increase in direct proportion to the output of gas at the moment. In the ordinary cone governor, as already described, this output is made to increase proportionally according to the height of the cone with regard to its seat. Consequently the lowering of the cone, and with it the bell of the governor, may be utilised to give the necessary indication of the quantity of weight required to give such pressure as may have been previously determined on; and, by means of these self-acting syphons, the fall of the bell causes a flow of water from the tank to the chamber directly proportionate to the height of the bell, and upon the rise of the bell, when the consumption decreases, the water in the chamber returns by the syphon tubes back into the tank in like proportion.

Fig. 8 represents the controlling arrangement, invented by Mr. James Milne and the author. A represents the bell of the governor, which rises and falls according to the outlet pressure, and to which is connected, by a chain, the valve or cone B, which regulates the flow of gas. C represents the tank of the governor made in a concentric form, water being in the outer portion only, marked D. G is a water chamber fixed to and forming part of the bell, consequently rising and falling in and out of the chamber H. K K are the two syphon tubes passing from the bottom of the water chamber G over the top of the bell to the bottom of the same on the outside. As the bell falls, due to an increased consumption, the water from the tank passes through the syphons into the water chamber in such quantities as to keep the surface of the water of the tank D and that in the chamber G at the same level. Thus, the lower the bell falls the greater the quantity of water in the chamber G, and in consequence the greater the weight of the bell, which is so proportioned as to occasion the desired greater pressure of gas to counterbalance it. It will thus be easily understood how this arrangement will modify the pressures, but before touching more particularly upon the effects this has upon the pressures in the district, it may be well to mention one or two other methods by which the same object is achieved.

Instead of the water being used for the purposes of loading the bell, a helix—or, if preferred, a pair—may be so fastened upon a shaft which also carries the wheel over which the counterbalance weight is suspended, that when a weight is fixed pendant from the helix, the varying distances from the centre at which this weight will hang may be made to put more or less weight upon the bell as it rises and falls.

This arrangement, which is the invention of Mr. Milne, is shown in Figs. 9, 10 and 11. A represents the ordinary bell with the cone B fixed to it. C represents the ordinary weights used to counterbalance the bell, D the helix, and E the weight pendant from it. G the centre of the shaft H. When the weight E is suspended from a point in the circumference of the helix F at its greatest distance from the centre G, as in Fig. 10, it is neutralising to a much greater extent the effect of the counterbalance weights C C, than when suspended from a point K in the circumference of the helix F at its least distance from the centre G, as in Fig. 11. Thus the varying distances of the points of suspension of the weight F from the centre G, regulate accordingly the outlet pressure of the gas.

Another plan is to make the balance weight chain with links of certain weights, so that the portion of the chain on the counterbalance weight side of the pulley is proportionately diminished, and the weight upon the other side increased to the same extent when the bell falls, thus putting increased weight upon the bell. A heavy arm with the weight at the end will also serve to replace the helix, and this when standing in a vertical position will exercise no influence, but as the bell falls will be carried to the side of the centre of the shaft and partially counterbalance the balance weight. A further method is to make the bell of the governor to be tapered upward, as shown in Fig. 12, instead of having parallel sides, so that the further the bell is immersed in the sealing liquid the smaller is the area of the bell at the surface of the liquid exposed to the pressure of the gas, occasioning a larger pressure of gas to counterbalance it. This is also the invention of Mr. Milne.

In all of these methods, it is necessary to note the position of the bell and cone when the maximum quantity of gas is passing through the governor at the maximum pressure found desirable, and also when the minimum quantity at the minimum pressure is passing. The distance of travel of the bell between these two extremes and the radius of the helix and of the arm, the weight of the links of the chain, or the degree of taper or slope of the sides of the cone, will govern the rate of increase of pressure thrown by the governor. With either of these governors the pressure is automatically changed entirely in accordance with the output of gas, so that the pressures are changed when required and not when it is thought that they may be required. The alterations of pressure are made so gradually that the line traced on a recording pressure gauge fixed quite close to the outlet of the governor will show—not as is usually the case when the weights are put on by hand, a series of steps which fall before the next rise occurs, but a gradual sloping line until the highest pressure is attained at the moment of the maximum output, and thereafter falling equally gradually until the minimum output is reached. The line practically never remains horizontal, unless the output of gas continues exactly even, which, in most gasworks, is never the case.

The advantages of such an automatic arrangement are so numerous that it is hardly necessary to dwell upon them. The avoidance of all possibility of jumping the lights in the district, of reducing the pressure when the output is at its smallest without endangering the power of supply at the right pressure, should such increased output be required, and the fact that the intelligence, or otherwise, of a man who probably has other duties to perform which may prevent him using what intelligence he may have at the right moment, must greatly weigh in favour of such an arrangement. In many districts the leakage account might be considerably reduced were such a piece of apparatus in use. Diagram 2 indicates the difference in the pressure thrown upon a district where such a governor is used, and Diagram 3 shows where a further modification of this principle is in use. If it be decided that the maximum pressure upon the district shall not exceed a certain amount, nor the minimum be allowed to be less than another certain pressure, the helix, water chamber, conical bell, or other governing arrangement, can be made so that, even should the output be increased much above what is anticipated, the pressure does not rise above the maximum pressure for which it is designed, and the same when the minimum output is reached. This then may show on the diagram a straight line during certain hours of the day and for a short period in the evening at the time when most of the lights are on.

A further use to which such a piece of apparatus might be put is for registering, with some slight degree of accuracy, the consumption or output of the gas. As the pressure changes with the output, so by a system of calculation the quantity of gas passing the orifice around the conical valve might be determined, and this, once found, would remain constant.

Where two gases of different qualities are made in a works and are mixed at an early stage in the process of manufacture, this system might easily be adopted for gaining some insight into the proportionate quantities of either which are being delivered into the apparatus for purification of the combined products. Of course it is not intended to suggest that this would give an indication to anything like so fine a degree as would be the case if a station meter were used for the same purpose, but there are many situations where such an apparatus might be fixed where a station meter would be impossible, and the cost of such a means of measuring the output would be distinctly less than that of a meter where considerable quantities had to be dealt with.

An idea at one time occurred to the author to make the revolutions of the station meter govern the pressure of the outgoing gas, but the low rate of travel which is necessary in the ordinary station meter prevented a satisfactory adaptation of this idea, and the author was thus led to examine the means by which the governor can be made to regulate the pressures by itself.

Before such an automatic apparatus as either of the last three which have been described could be put to work in a satisfactory manner upon any district, it would be necessary to make a series of tests of the pressure in various parts of the district, and also to examine carefully the capacity of the various pipes supplying that district, so that the point of minimum pressure might be previously determined. It would also be necessary to so regulate the pressures that the supply at that point would be at all times sufficient to supply the consumers, despite any calls which the mains between that point and the works might be called upon to supply. The author regrets that, owing to the death of a well-known gas engineer (Mr. Linton), the series of experiments intended to have been carried out during the recent winter have had to be postponed, which would otherwise have conclusively proved the advantages of this system when supplying a large district served by three distinct trunk mains worked by three governors, all fitted with this apparatus at one centre. Sufficient, however, has probably been said upon this subject to enable those interested in this important question to examine into the merits, or otherwise, of the system, and it is hoped that any of those present who may have any opinions either opposed to or in favour of the arrangement here shown, will state their views, so that, if possible, a further improvement may be made, and the general work of the gas engineer rendered a little less arduous and worrying than it is at present.

DISCUSSION.

The PRESIDENT said Mr. O'Connor had given the Society a very interesting paper on an appliance which was not only of great use to the gas engineer but one in which the consumer must be greatly interested. He had further taken the trouble to illustrate his paper by an excellent series of diagrams. No doubt the Society would award the author a hearty vote of thanks.

The vote of thanks was carried unanimously.

Mr. C. GANDON said that the paper was most interesting to gas engineers engaged in the distribution of gas throughout a district. A station governor was a very important instrument, and enabled them more or less to regulate the supply of gas to the consumer at different hours of the day and night. His own experience had been connected with the first or primitive form of governor to which the author referred, and with which he was bound to say he was very well satisfied under ordinary circumstances, though he would not deny that the appliances which had been described in the paper were improvements upon it. They seemed, however, to be more theoretical than was necessary under ordinary conditions. If gas engineers could have a perfectly level district, and maintain the pressure at all times at what was required for the supply, such an apparatus as that described would be very useful. But, unfortunately, there were variations of level in almost every district, and it was therefore most difficult to make an apparatus which would adjust itself automatically. The original governor shown in Fig. 1 was a most beautiful appliance on account of its simplicity. Complication led to difficulties. He believed that an even more simple governor than the one in ordinary use once existed, though he had never seen it in action. It was simply a vessel filled with moss, or something of that kind, and had a disc of wood at the top loaded with weights; the material under the disc was elastic and rose up when the weights were removed: but he did not recommend that form of governor for use at the present time. No doubt an automatic governor would be extremely useful in the case of small gasworks, which could not afford to have a man constantly watching the consumption; but, as a rule, he should prefer to trust to a governor of the ordinary form with a man to manipulate it.

Mr. J. HEPWORTH said he had been a user of governors for the last thirty years, and had been much interested in the historical account of governors given in the paper. But he had been looking for the names of other inventors besides those which the author had given, and he had been thinking of such names as those of Caink, and Connolly, and Hopper, and Elster, and Beechey, and Cowan, all of whom were well known in connection with improvements in station governors. If he was not mistaken, the governor illustrated in Fig. 2 was invented in France. He knew it was largely used in this country at the present day. The third one was also one for which they were indebted to a French inventor. It was quite clear that the first desideratum in a governor was that it should give an outlet pressure which would not vary although the inlet pressure did. That desideratum was not quite reached in the earlier forms of the apparatus to which reference had been made, but he thought that everyone would agree that such a governor was available at the present time, although the author had not said so definitely in his paper.

In the second place they wanted something which, if possible, should automatically actuate the pressure. The author referred to an interesting invention, which came out something like twenty years ago, for changing the pressure by clockwork. The clock was intended to do at the right moment what the man in charge ought to do, though he might omit it if he happened to be asleep or out of the way. But the object of the author was to bring before the Society a further development towards perfecting the governor, namely, a means of rendering the pressure more uniform than it would be in a governor attended to either by clockwork or by hand. He could not tell by the cursory glance he had made of the drawing how far the governor last described would secure that end. If it would secure it, it would serve an excellent purpose and would meet with the approval of many gas engineers throughout the country. He should like to call attention to a system invented by Mr. William Cowan, which had found no place in the paper and which would really secure the end which was sought by the author. He should not have referred to it but for the fact that he had worked it himself, and could, therefore, speak of it from actual experience as being an invention which satisfactorily accomplished the object which was aimed at, namely, the variation of the pressure at the works in such a way as to secure a uniform pressure at any part of the district chosen and fixed upon.

Two ways were proposed for securing that end. It was first suggested that, from the point in the mains where the pressure was uniformly found to be lowest, a pipe should be carried back to the governor at the works, so that the pressure at the low-lying district should be made to carry back an intimation to the station, and be the means of loading the station governor with water or taking off the water, and so altering the pressure as might be desired. It was further proposed that it should be done by electrical communication. That was a method of which he had had some experience, and it worked well during the time he had it in charge. He was a little surprised that that system had not been referred to in the paper. An article on it had appeared as lately as 1893 in 'The Journal of Gas Lighting.' The system really had secured an equal pressure at that point of the mains where the pressure was invariably the lowest, and therefore it secured an equal pressure between that point and the works. Mr. O'Connor had pointed out that that was one of the results to be aimed at.

The governor which Mr. Gandon appreciated so much and the clockwork governor were not perfect, for they only did what they were told. He was sure that the gas engineers of the country would be glad to find a means of equalising the pressure of gas throughout a district according to the varying circumstances of day and night.

Mr. W. T. Sugg said that Fig. 1, coupled with the remarks of Mr. Gandon, had carried him back to the time when he was first at the South Metropolitan Gasworks. At that period he used to regulate the pressure at Greenwich with a large diameter holder of the old Clegg pattern. The variation in the governor was slight, one reason being that the holder was of very large diameter, and the other reason was that the holders were much smaller, and the coupling of the holders did not make much difference in the pressure or otherwise there might have been an irregularity. No doubt there was a slight irregularity, but that was caused by the density, or rather the pressure, of the gas on the cone itself. As the pressure increased, and the density of gas increased, it naturally had the effect of lightening the cone to a certain extent, but the diameter of the holder was so large that it made very little difference. So long as they could employ a very large holder, and they had not a very great variation in pressure, there would be very likely all that could be desired. In the case mentioned, if a cloud came over Greenwich, although he could not see it he knew that it was there, because the pressure would gradually drop. That showed that the quantity of gas allowed to pass through the governor by the weight that was put upon it was not sufficient, and another weight had to be put on. That was the general experience of everyone who had had to do with the regulation of pressure by means of a governor.

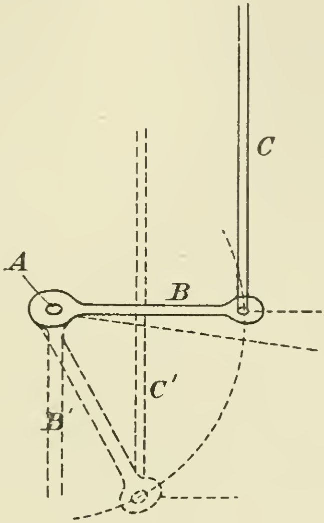
He did not know whether he was right in supposing that the idea of the tubes in the new invention was to equalise the pressure. He observed that there was only one cone, and that was exactly the same as the old Clegg cone. If it was made for that purpose, he quite understood it. With regard to the curves of the pressure which Mr. O'Connor had shown, it looked as if the variations of the pressure would hardly meet the requirements of the public in every place. The arrangement appeared to be unsuitable for any place except a small town. In London the demand was so exceedingly changeable, even from hour to hour, that it would be impossible to regulate the pressure in that way so as to satisfy everybody. He thought that the pressure would have to be very much increased in order to keep a sufficient pressure at the lowest point of the district. To work the gas stoves would take at least one inch ; and the new incandescent burners took at least one inch. That would always require one inch to an inch and a quarter on the main at the lowest point. If it was much more than that at the highest point, the only way to correct the pressure would be to put on a governor at the consumer's own place. The pressure could not be kept uniform by the governors at the gasworks. In a hilly place like Folkestone, for instance, the pressure at the highest point was greater than at the governor. At Folkestone the Lees took away almost all the pressure from the lower town. That was stopped by putting a dry governor underground to regulate the pressure on the Lees, and reduce it to about an inch and a half. He did not think that the new governor was meant to regulate in such a case as that. There had been one or two governors made in France. M. Girard had carried a pipe from the exterior of the governor to the centre of the district, so that a falling off allowed a greater pressure to be put on automatically. In that case there was one concentric gasholder inside the other, so that if the pressure fell off in the town, the gas would come out of the other gasholder and cause a greater weight to come on the inner gasholder, which was really supplying the gas.

The only thing which he saw in the other governors was, of course, the double cone. He did not recollect whether that was a French invention or not, but the gas gave an equal pressure upon both. The only difficulty was that the regulation of the lower cone was an awkward job, because both cones had to be got up to their seats exactly at the same time, and when the governor was working very close to the seat, of course one valve was doing the work and the other was not. It was very difficult to get both to work alike. It was not quite so easy as in the case of the old tappet valves, which used to be used in the old steam engines. In that case the greatest difficulty was always to get the two to work together. When the cone of the governor was near its seat during the day a slight alteration of pressure might very often cause it to go right up and stop the gas. He thought that the best way to get over that was to have a by-pass governor round the lower part. The by-pass would do all the work in the day, and the big one would come into action by itself directly circumstances required it. When the pressure of the bigger one was increased, the one that was only provided with a weight for the day pressure would be shut up. That plan had been carried out, and it seemed to answer very well. Circumstances had so changed from the early days that the question of governors would have to be reconsidered, and he supposed Mr. O'Connor had been considering it, and the result of that consideration seemed to be very ingenious.

Mr. J. L. CLOUDSLEY said he had been very much interested in the historical record of the governor question. Mr. O'Connor had referred to the double-cone governor as intended to deal with changes of inlet pressure, and no doubt it had that effect, but being a double-beat valve it did not control the gas as a single cone would. He believed that in designing a governor, say, for a 24-inch main, it had been found that the seat of the valve should only be about one-half the area of the pipe. It was familiar to gas engineers that gas would much more easily pass through a knife-edge valve, or something equivalent to a knife-edge valve, than it would even through a short length of pipe. Probably some of those present had been surprised at the large quantity of gas which would pass through a small opening when a valve was opening or closing.

With regard to the automatic arrangement by which Mr. O'Connor proposed to maintain the pressure of a district, of course Mr. O'Connor and most of those present would know that it was not a new idea. The first person to develop an arrangement of the kind was Mr. Keeling, who was manager of the Reading Gasworks about forty or fifty years ago. He had a small water vessel attached to the end of the counterbalancing chain, and close by it, connected by a tube, there was a stationary vessel, and as the governor fell the water passed from one vessel into the other, but for various reasons that arrangement was unsatisfactory. Mr. Connolly of New York, and several others in this country, had attempted the same thing, but he (Mr. Cloudsley) doubted whether they had succeeded, for there was one very fatal defect which apparently Mr. O'Connor had not anticipated, and that was that the changing of the pressure would alter the position of the bell according to the position of the valve. If the valve opened to a considerable extent and the inlet pressure changed, there would be a considerable unshipping of the water, and consequently a considerable falling off of the outlet pressure. Unless that could be provided for by an attendant at hand, it would create serious consequences. That was a difficulty which had always blocked the way.

Mr. W. Worby Beaumont said he had been very much interested in several points which had been referred to by Mr. O'Connor, quite apart from the appliance which he had described. First, he would ask him to inform the meeting in his reply whether the Mr. Clegg he had referred to as the inventor of the ordinary governor was the Mr. Clegg of atmospheric railway fame. The author had mentioned a point which made one suppose that some of the inventors of governors had had a very good knowledge of what had been done in the way of governing by means of a cataract, used in the early Cornish engine and even before that, as the same principle was brought into play. With regard to the governor with a butterfly throttle valve, it occurred to him that the objection which the author had mentioned in connection with it might be got over by fixing the arm B on the throttle-valve spindle A, in such a way that the unit movement of the controlling rod C gave greater or less movement to the valve, as shown in the annexed diagram. Unit movement of the rod C, shown in full lines, would give similar angular movement to the end of the arm B. When in the position shown in dotted lines, the unit vertical movement of C′ would give about double the angular movement of B′. Between these extremes any variations for similar movements could be obtained, or similar movement for varied area of opening.



That matter had also been mentioned by Mr. Gandon, and he had no doubt that that which he had mentioned had also been gone into by some of the many inventors to whom Mr. Sugg and Mr. Hepworth had referred. The governor balance alluded to by Mr. Hepworth seemed to a person not acquainted with such matters to offer the means of working exceedingly advantageously, with the exception that it of course involved a different set of apparatus, and carrying of the electric wires considerable distances for the purpose. Mr. Hepworth might perhaps give a little more information as to the nature of the apparatus which the electrical current worked. He (Mr. Beaumont) had not gathered how it was that the variation of the pressure at one end caused the uniformity at the other.

It was very interesting to hear what Mr. Sugg mentioned as to very small variations in pressure causing a sufficient variation of the gas to affect the action of the governor bell. When it was remembered that coal gas had such an exceedingly small density—roughly, about half that of atmospheric air—it seemed remarkable that governors should be so sensitive that a slight difference of density would make a difference in what might be called the flotation power of the bell. It made one wonder whether it would be possible to make use of the fact by making a bell of light material and perfectly gas-tight, so that it might have a great flotation power and be used as a governor.

Mr. F. W. CROSS said the only point which struck him was the question of how the governor was controlled, or how it was affected, by the inlet pressure and the variations of pressure in the cupping or uncupping of the holders, or by the change of holders. Managers experienced a great deal of trouble from that cause if the governor was not sufficiently sensitive. It appeared to him that the syphon tubes were supposed to regulate the difference of pressure caused suddenly; but he should like to know whether the syphon tubes were sufficiently quick in their action to counteract the difference of pressure. It was not in the nature of things that gas engineers should have a working experience of many different kinds of governors, and they did not investigate such matters unless they had to put in a new governor. There was only one governor which he had had experience of putting into position, and that was not mentioned in the paper. That was the equilibrium governor. He had to put it in himself at Hong Kong, and therefore perhaps he took a more lively interest in the matter than he could have taken otherwise. He had two mains leading from a governor house, and the outlet of one was connected to the other, one of those governors being used only on certain occasions when the demand necessitated it. On one occasion, when the pressure was full on the small governor, the valve of the other was opened suddenly so that the two mains were filled with gas from the holder. There was not the slightest variation. That would not have been so if the action of it had not been sufficiently quick to counteract the sudden increase of pressure.

The author had alluded to an equilibrium of pressure all over the district, but that must be only a dream of gas engineers, for districts varied greatly in their levels, and also in their nature in consequence of the expanse of business. Mr. Sugg had alluded to street governors. Those were very important in many places. In Hong Kong he had had experience of them. In consequence of the streets being parallel to one another on rising ground, the gas had to be controlled solely by means of dry street governors. The streets rose to a height of 1200 feet above sea level, and therefore it was quite certain that no governor stationed at the works would be able to control the pressure.

Mr. J. HEPWORTH, referring to Mr. Beaumont's remarks, said that he found that he had a very brief description to which he had referred. It was contained in an article in 'The Journal of Gas Lighting' on the 16th May, 1893. The principle of the invention was the "automatically regulating the loading and unloading of gas governors by the pressure of gas in the main of a district remote from the governor." The article said, "No special form of governor is necessary for the purposes of this invention," but it must be a water-loaded governor. An auxiliary holder was connected with the main at the point where the pressure of gas was lowest. The article went on to say, "The gasholder bell is itself operated by the pressure of the gas in a district more or less remote from the governor. When the gasholder occupies a position near to the governor the pressure from the main is transmitted through the return pipe. In this case the bell actuates the valves mechanically and directly. But when no return pipe is employed, and the gasholder is removed to a remote district, and connected with the main there by a short length of pipe, the valves are in that case fixed on or near to the governor. In this case the valves are operated electrically and indirectly by the falling and rising of the distant gasholder, the movements of which cause electrical currents to be completed or interrupted, and thereby to operate the electromagnets which open and close the valves. The reduction of the pressure in the remote part of the district with which the auxiliary gasholder is connected will, by bringing down the gasholder bell, open the supply valve through which the water passes to load the governor. By this means the falling pressure in the remote district will be almost immediately restored to the normal point by the governor receiving an extra load." As far as the principle of that invention was concerned it was a matter of no moment whether the return pressure pipe or the electrical conductor system was employed.

Mr. HENRY O'CONNOR, in replying upon the discussion, said that Mr. Gandon had pointed out again that the pressure should be kept up even at the most distant parts of the district, that was to say, it should be sufficient to supply people in the most remote position from the gasworks; and Mr. Gandon seemed to think that the old governor represented in Fig. 1 would practically answer the purpose. But, as subsequent speakers had pointed out, the old pressure governors did not give any means of putting the two valves in equilibrium. He believed that was the principal reason why there were not many of them at the present time. Mr. Hepworth had alluded to various governors having been omitted from the paper. The explanation of the omission was that he, Mr. O'Connor, found it quite impossible to mention all the governors that had been invented from time to time, and he had consequently confined himself to those which were more commonly in use in this country, and which contained simple points all leading forward to one end. The arrangement which Mr. Hepworth had suggested, with the length of pipe or the electrical communication, he had heard of a good many times, and he had heard it very adversely spoken of. The power which could be exerted by an electrical appliance for opening a water valve or cock was comparatively small, and any valve or cock that he had ever heard of required a considerable amount of power to open or shut it, if it was capable of remaining tight to the ordinary pressure of water which might be behind it. That seemed to sum up an objection to the electrical method; and the fact that the wires would have to be carried underground or overhead would entail a considerable cost, and, further, the current would be likely to pass to earth before it arrived at the works, if any abrasion took place on the coating of the wire. If anything went wrong with an apparatus which was expected to work automatically, the error was not corrected so easily as a defect in an apparatus which required constant supervision.

As to the question of the pipe, the most distant part of the district where the pressure would be at the lowest was the part where they would require the governing holder which Mr. Hepworth spoke of, and if a special main had to be laid simply for the purpose of carrying back and informing the manager at the works of what was being done in the district, an enormous expense would be incurred. Again, the main would be liable to leakage, and by the time that the pipe got to the works they would have lost a considerable amount of the pressure that was placed in the pipe at the other end. If that arrangement was required, the governor in Fig. 4 would be admirably adapted to work it. The experiment with that governor showed the maximum at which it would be able to comfortably work with the pipe. A small holder could be placed half a mile off, and it would be quite easy to cause the valve to be actuated by means of the local pressure in the district acting on a secondary governor, and, by means of the pressure thrown on the smaller holder, to exert the required pressure on the under side of the valve, and lift it and allow the gas to pass through.

He was afraid that Mr. Sugg did not quite master the idea for which he (Mr. O'Connor) was proposing the new governors. They were for the purpose of increasing the outlet pressure when the quantity of gas going out from the works was increased, and so allowing, if the mains were small in the district, a larger quantity of gas to pass through these mains, and enabling the consumer, where the pressure was at its least, to have sufficient pressure to enable him to get the light and heat that he might require at all times of the day, no matter what consumption was going on between him and the works, and no matter what pressure was taken up by the consumption, or what leakage might be taking place. Mr. Sugg had mentioned the question of dry-pressure reducers. He (Mr. O'Connor) should like to know the size of the diaphragms of the governor Mr. Sugg referred to as having been used at Folkestone.

Mr. SUGG said that he believed that it was 2 feet 6 inches in diameter. It was an 8-inch main. It was put down a very long while ago by Mr. Barlow.

Mr. O'CONNOR said that the arrangement in Fig. 4 for the lower portion of the governor was equally adapted for the purpose of reducing the pressures in the district. It only required a float. He believed there were hundreds of others all serving the same object of closing off the pressure. They were set at a certain pressure, say 1 inch, and no matter what pressure might be behind the reducer, the pressure on the outlet would always be 1 inch less. That was the principle generally adopted. As to the double system of governors which Mr. Sugg had mentioned, it seemed to him (the author) that when the second governor came on, the pressure would suddenly rise, because the lower governor was set at a small pressure, and it was only when that was overtaxed that the other was brought into operation.

Mr. SUGG said that the second one was brought into action by an extra weight being brought upon it, and that shut up the other.

Mr. O'CONNOR said that in that case it was not automatic. With regard to the question asked by Mr. Beaumont as to the identity of the Mr. Clegg referred to in the paper, he was sorry to say that he could not answer it. Mr. Beaumont spoke of the density of the gas. That was an expression used by Mr. Sugg, and Mr. Sugg did not seem to mean necessarily that the density was increased, but he was speaking more particularly of the pressure at which the gas was standing inside the governor.

Mr. SUGG: Inside the governor valve.

Mr. O'CONNOR, resuming, referred to the question which had been mentioned by Mr. Cross, as to the making the new pattern governors, commonly known as equilibrium governors, and said that the addition of the equilibrium portion had been purposely omitted, so as not to hide or be confused with the loading arrangement; any system could be fitted to it, either the double-cone system, or the secondary chamber, or the chamber outside. As to the question of the water getting in and out, the tubes were purposely made so that it should not get in and out too rapidly, and that any sudden jerk should not have the effect of altering the pressure. The idea was not merely to get an equilibrium governor. As to the question of hilly ground, such as Mr. Cross had spoken of, there was no governor which would deal with cases of towns which rose many hundred feet in one particular direction, and it might be safely said that there never would be such a governor. In such a case particular methods would have to be adopted. It was only by means of governors at particular parts of the district, or by pressure reducers, that they could alter those vastly different pressures which occurred at different heights above the sea-level.

PLATE I.

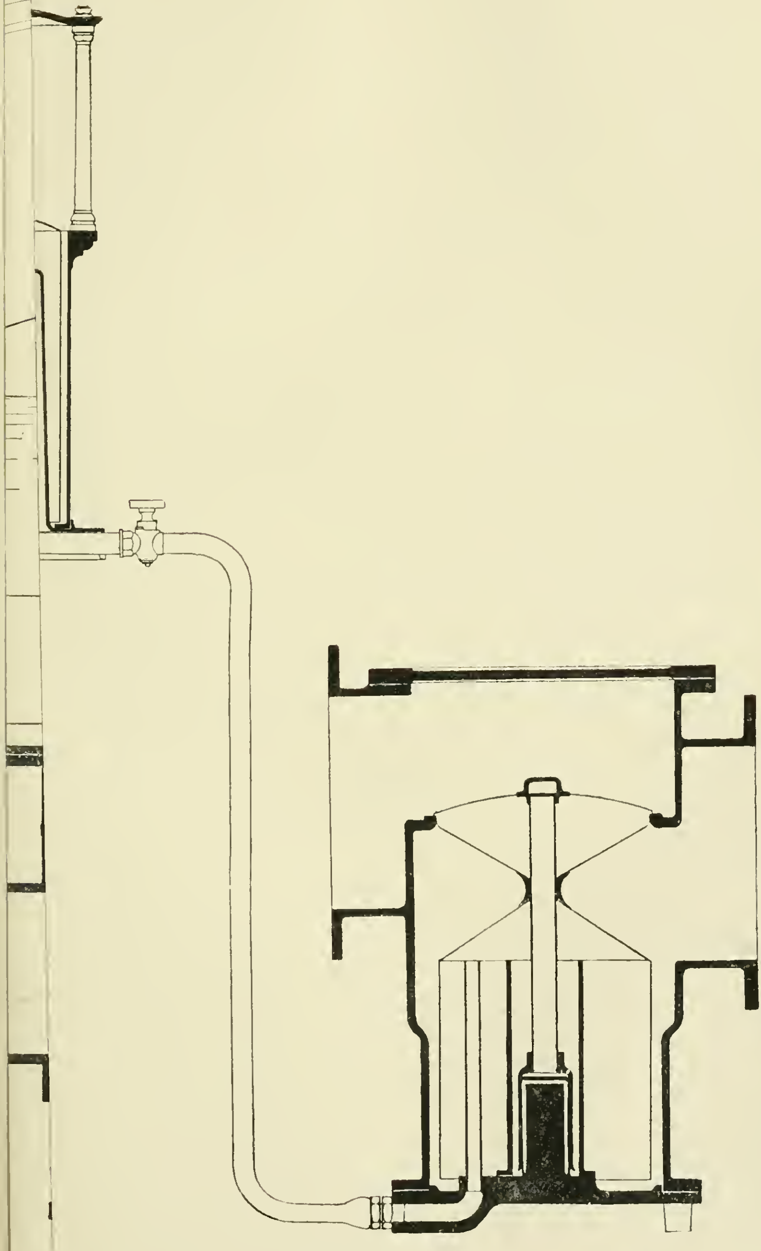


FIG. 4.

PLATE I.

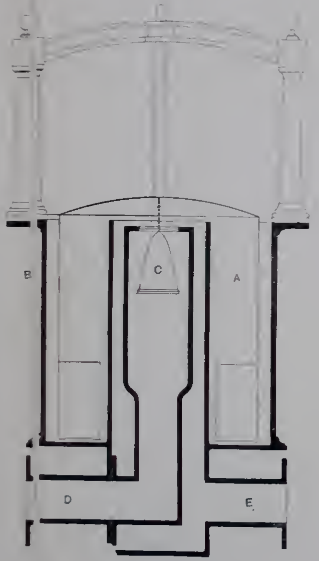


FIG. 1.

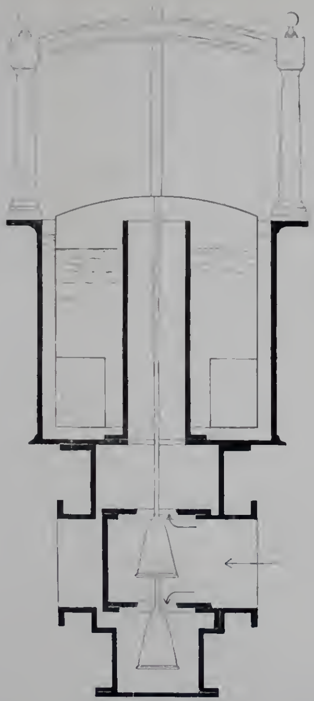


FIG. 2.

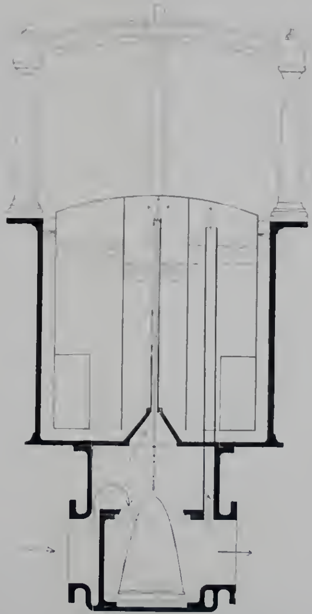


FIG. 3.

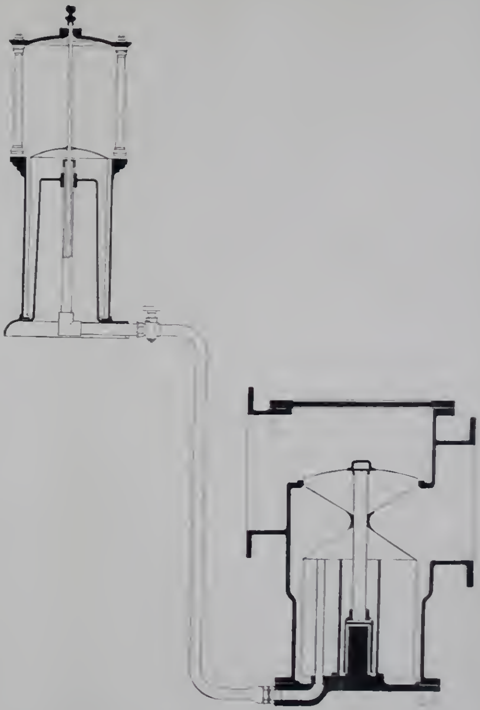


FIG. 4.

Plate II.

IG. 8

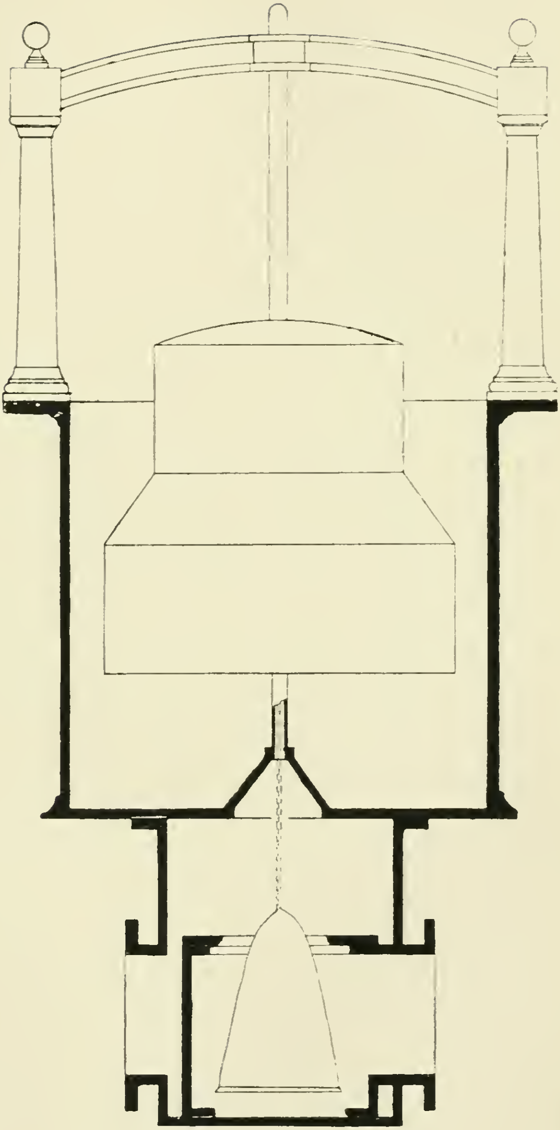


Fig. 12.

PLATE II.

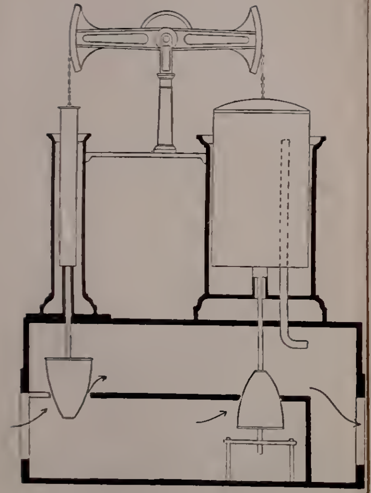


FIG. 5.

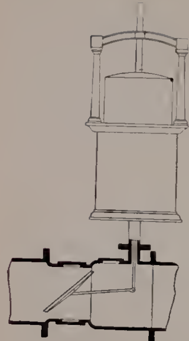


FIG. 6.

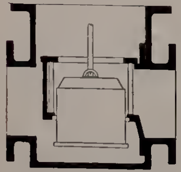


FIG. 7.

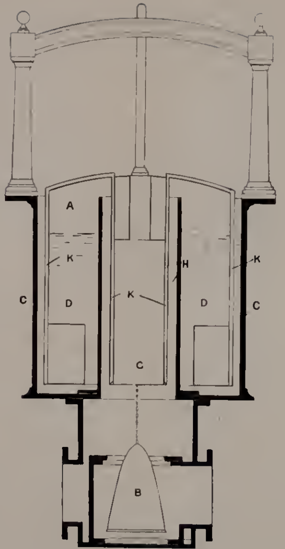


FIG. 8.

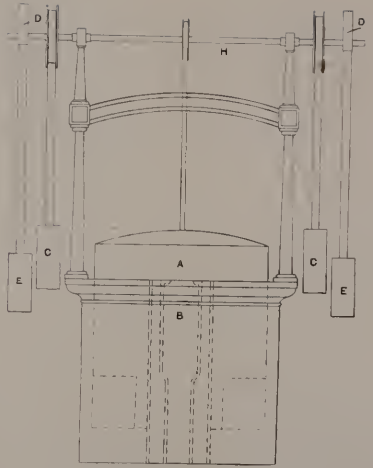


FIG. 9.

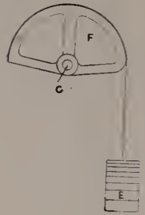


FIG. 10.

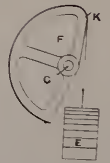


FIG. 11.

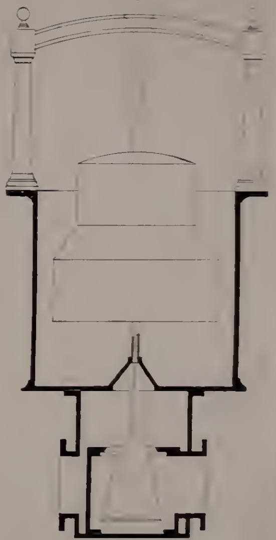


FIG. 12.

GAS PRESSURE REGISTER.

Diagram 1.

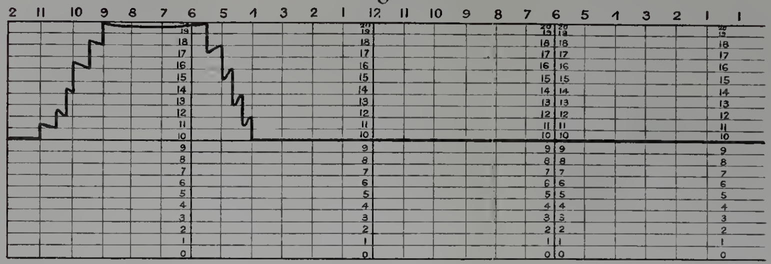


Diagram 2.

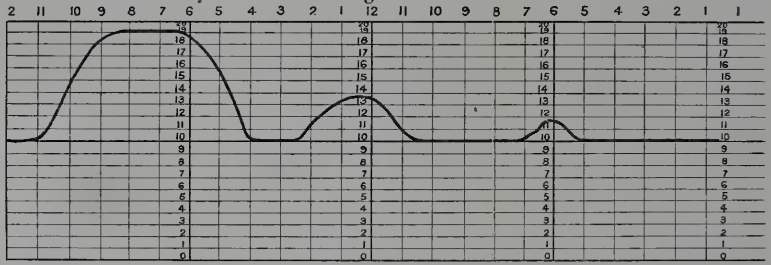
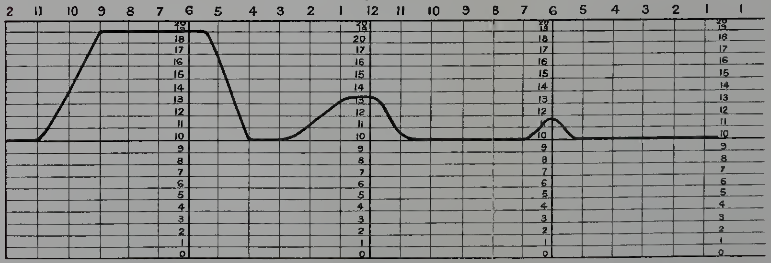


Diagram 3.



E.&F.N. Spon Ltd., London.

June 14*th*, 1897.

GEORGE MAXWELL LAWFORD, President,
in the Chair.

THE COMPRESSION OF AIR BY THE DIRECT ACTION OF WATER.*

By Professor Herbert Williams Umney.

In bringing before the Society an improved method of compressing air, the author trusts that to the Members generally, and to mining engineers in particular, the subject will be of special interest. He refrains from detailing the mechanical difficulties of compressing air, with which engineers are conversant, and would only specially allude to those objections which have great weight commercially, viz., the initial cost in providing suitable means for retaining air at a low temperature, the working expense arising from repairs to intricate parts, and the necessity of skilled attendants. The general principle underlying the work which the author is about to bring under notice is familiar to most in one form or other. For instance, it is well known how readily water breaks into foam, which is due to its being impregnated with air in minute bubbles. Since bubbles rise in water at a velocity depending upon the size of the bubble, it is obvious that air drawn into a current of water moving downwards with a velocity in excess of that at which the bubbles rise, will be carried down and subjected to a pressure corresponding to the depth attained, and, moreover, the compression will take place isothermally, a process which is not accomplished by any other compressor. If the direction of the water be then altered to a horizontal one, the air will rise in a few seconds to the top of the passage and accumulate in a suitable chamber under the desired pressure.

As an illustration of a means for carrying out this work the author gives a diagrammatic view at Fig. 1, suggested by Mr. Frizell, of Boston, U.S.A. A shaft is sunk to a depth corresponding to the pressure of air required (i.e., to a depth of

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* A Society's Premium was awarded to the author for this paper.

2·3 feet per pound pressure), and at the foot of the shaft a horizontal tunnel is driven to a point below the fall, where it meets a vertical shaft. The water then passes down the one shaft, along the tunnel, and is discharged by passing up the second shaft. The top of the tunnel is not exactly horizontal, but rises gently from both ends to a point where a chamber is constructed for the accumulation of the air. The whole forms thus an inverted syphon, through which the water flows with a velocity depending on the effective head. The length of the tunnel will be controlled by the necessity of placing the entrance to the chamber far enough from the descending branch to admit of the complete escape of the air bubbles.

The effective head will depend upon the quantity of air carried by the descending branch. This can be regulated at will, and furnishes the means of controlling the velocity. The method of introducing air bubbles into the descending column is by surrounding the shaft with a bulkhead of masonry, over which the water is led in a covered channel, the bottom of which rises a little above the highest level of the water. The arched space forms a gallery for regulating the admission of air by a number of holes at A on the descending branch of the syphon channel, where its direction is nearly vertical. At the point A the pressure within the syphon is less than that of the external air, and the latter will flow in through any opening. Should the external water even rise as high as the top of the gallery, the internal pressure will be negative at A.

This is evident from the fact that the flow does not take place by the direct action of gravity, but by the excess of the atmospheric pressure over that in the channel near the entrance. Were the entrance to the syphon closed by a gate, the pressure inside would be less than that of the atmosphere to a point as low as the surface of the water below the dam. It is apparent that the syphon channel extends entirely round the vertical shaft, except at one point, where it is interrupted by an entrance to the gallery. It is provided with a pump, worked by air from the chamber, to produce the vacuum when required, and remove—from time to time—the small quantity of air eliminated from the water. By allowing the air to enter the summit of the syphon the flow may be suspended at will. An account of this proposal was embodied in a paper by Mr. Frizell in 1877 (published by the Franklin Institute), and the author would here acknowledge his indebtedness to that gentleman for information regarding experiments carried out in the United States about that time.

It was well understood that a practically satisfactory efficiency could not be obtained from a model, since, with a low velocity, narrow passages, and small head, the resistances bear a large proportion to the motive power, and may even absorb it altogether. The first apparatus tried, Fig. 2, consisted of two glass tubes, 1¼ inch diameter, fixed into the cover of a strong glass vessel so as to be air-tight. The shorter tube, about 9 feet in length, terminated in a small tub, whilst the other was formed into a syphon at its upper end to dip into a similar tub. This latter tube had a small orifice at the summit, closed by a flap valve, for exhausting the air, and a minute orifice at a point just above the level of the syphon end. The difference in level of the two tubs or head was from 8 to 12 inches, and the pressure of the air accumulated was about 4 lb. per square inch. Having filled the glass vessel, tubes and tubs with water, the syphon was set in action by placing the finger over the minute orifice, and exhausting the air by applying the mouth to the summit orifice, then closing the latter. The pressure within the tube at the minute orifice being a little less than that of the atmosphere, the air enters there and is carried downward by the current and lodged in the receiver. No unforeseen difficulties being developed by this experiment, it was decided to try the method on a larger scale, as shown at Fig. 3, and 3-inch pipes were used, with a cast-iron chamber. The pipes terminated as before, except that the longer one had two syphons instead of one, and additional minute orifices (just above the surface of the water in the chamber) for the admission of the air. In this case the difference of level was increased to 25 inches, and the length of the tube to 12 feet, but the efficiency only reached 26½ per cent.

Emboldened by such successful results from so simple an appliance, Mr. Frizell decided to make a still larger experimental plant, and this is illustrated in Fig. 4. The apparatus consisted of a strong wooden tank at the bottom of the pit, with two vertical shafts rising to the surface of the ground. The shaft for the descent of the water was 15 by 30 inches, and that by which it ascended was 24 by 48 inches. The air chamber was situated between the vertical passages, and constructed of 4-inch pine planks with a lining of lead, and fitted with a cock for allowing the air to escape. This chamber was separated from the horizontal passage below it by a partition of boards, laid with openings which allowed the air to pass freely into the chamber. In order to prevent any tendency of the air bubbles to amalgamate, when the direction of the passage was other than perpendicular, the descending shaft was contracted at the bottom so as to somewhat increase the velocity of the water at that point. Although the passage was flared out in a direction at right angles to the shaft, yet a certain amount of head necessarily was lost. When originally constructed, the upper part of the shaft was provided with a syphon, as in previous arrangements, but the difficulty of exhausting the air was so great that other means were sought for impregnating the water. The method adopted is that shown in Fig. 4, namely, by allowing the water a slight fall at its entrance. The tests of this work are recorded in the 'Proceedings of the Institution of Civil Engineers' (vol. lxiii. p. 347), when the maximum efficiency obtained was 52 per cent., with a head of less than 5 feet.

Although it is within the author's knowledge that a somewhat similar apparatus for compressing air was used in Spain some centuries ago, yet he is not aware of the adoption of this principle with anything like satisfactory results until recently, when Mr. Taylor, of Montreal, patented a more effective method of impregnating the water with air, and erected a plant at the Dominion Cotton Mills in Canada. The plant, shown at Fig. 5, consists of a shaft 6 feet by 10 feet, sunk to a depth sufficient to obtain the pressure, 52 lb., required, and within this is fixed a wrought-iron tube, down which the water can pass. The shaft is sunk parallel to a depth of 112 feet, and then for a further distance of 16 feet it is enlarged to 20 feet diameter. Owing to the nature of the ground, which was composed of layers of running sand, it was necessary to line the main shaft, and the timber used was 8 × 8-inch hemlock, with sets 4 feet apart. The timber extends from a point 3 feet below low-water level in the tail race to a depth of 72 feet, of which the last 20 feet is in the rock. All the timber above the rock is backed with 2-inch hemlock plank and filled in. The head of the shaft consists of three stone walls, forming three sides of a square, the walls being 14 feet in height, the space of 13 feet between the sides being the opening for the tail race.

The down-flow pipe, which need be only of sufficient strength to carry the weight of water and pressure of the working head of the water, is made of $\frac{5}{16}$ wrought-iron plate, 3 feet $8\frac{1}{2}$ inches diameter. The lower end of this pipe is gradually increased to 4 feet 8 inches, and its total length is 136 feet. The interior surface of the pipe is smooth, having butt joints held together by 4-inch straps riveted to the sections, and all the holes being countersunk. In the top of this pipe, a 10-feet telescoping pipe is inserted, and on this a cast-iron circular headpiece is fitted, over which the water falls, the diameter of this ring being 4 feet 8 inches, so that the thickness of the water passing may be reduced to a convenient amount. Over this headpiece a frame is erected, and from it are suspended thirty air inlet pipes, 2 inches diameter and 4 feet long, with the lower ends flatly welded. From each of these pipes thirty-two $\frac{3}{8}$-inch pipes branch into the water as it passes over the head, so as to introduce air bubbles into the water as it passes down. The combined headpiece and telescoping pipe are supported by a $2\frac{1}{2}$-inch square threaded screw, which passes through a timber spanning the top of the tank. A hand wheel with nut attached supports the screw and enables the headpiece to be raised or lowered as desired.

Around the head of the pipe, 3 feet below the top, is fixed a tank 12 feet diameter and 12 feet high, into which the water is led by a suitable conduit. Around the lower end of this down-flow pipe a chamber, 17 feet in diameter, 12 feet high, is constructed. The top is conical, rising 2 feet to that point where it is connected to the pipe, which projects into it altogether 9 feet, so that its lower extremity is about 8 feet from the bottom of the shaft. The bottom of this chamber is open, and rests upon cast-iron legs, which raises it 16 inches above the bottom of the shaft. In this chamber an apron 12 feet in diameter is fixed opposite the pipe, and 14 inches below its end, so as to deflect the water and permit of the air bubbles separating. In furtherance of this object, a second apron, 5 feet wide, is fixed to the sides of the chamber 14 inches below the outer edge of the other, in order to check the water before it is able to escape from the chamber up the shaft into the tail race. Suitable pipes are fixed so as to admit into the main chamber the air which has separated from the water in passing over the aprons. The compressed-air main, 7 inches diameter, passes through the water on its upward course, so as to maintain it at a low temperature, and on the top is fixed a self-acting regulating valve, shown at Fig. 6.

This valve is placed for the purpose of preventing the water from entering the air pipe, should the supply in the separating tank at any time fall short of the demand. As the air fills the separating tank, the pressure increases by a few pounds. When the pressure lessens to a certain degree, by the rise of the water, the valve closes automatically before the water can reach to within 15 inches of the top of the separating tank, and thus adjusts itself to the supply of air from the compressor. The extreme condition, arising when the point of separation of the air and water falls to the level of the tube, a condition resulting in the forcing of the water up the main tube by the air, is obviated by placing a blow-off pipe discharging above the tail-race. This 4-inch pipe has on the end an elbow with a short piece of pipe, and the latter, having its upper half removed, has a pair of plates secured to it. This plant was tested by Professor McLeod, of McGill University, Canada, who found that when 4005 cubic feet of water per minute were discharged with a fall of 22·3 feet (the available horse-power being 168·9), the quantity of air delivered was 1095 cubic feet per minute at atmospheric pressure (the compressor pressure being 52 lb.), making the actual power of the compressor 105·3 horse-power, which shows an efficiency of 62·4 per cent.

In this apparatus the method of impregnating the water with air is merely an application of the Pitot tube, which, in its simplest form, is a glass tube with a right-angled bend, having its point tapered usually at an angle of 60 degrees to meet the stream without shock.

When the tube is plunged vertically into a stream to any required depth z below the free surface, with its mouth pointing up-stream and normal to the direction of flow, the water rises in the tube to a height h above the outside surface, and the weight of the column of water $z + h$ high is balanced by the impact of the stream on the mouth. Hence,

$$w\,\mathrm{A}\,(z + h) = w\,\mathrm{A}\,z + k\,w\,\mathrm{A}\,\frac{v\,2}{2\,g},$$

and, therefore,

$$h = k\,\frac{v\,2}{2\,g},$$

A being the sectional area of the tube, v the velocity of flow at the given depth, and k a co-efficient to be determined by experiment having a mean value of 1·2. Now exactly the reverse happens when the direction or the taper of the tube is with the stream, as then, instead of there being an excess, there is a defect of pressure. Obviously, then, we can calculate what speed the water must flow so that the difference of head between the two ends may be sufficient to cause the required quantity of air to flow along it.

In order to ascertain the probable efficiency of such a plant the author has calculated out the hydraulic losses in the different parts of the apparatus. The chief source of loss is that due to the air bubbles rising. The velocity of rising increases as the square root of the diameter of the bubble, which diminishes in size according to the cube root of the pressure. The other losses are those due to entrance, to frictional resistance in the pipes, to shock, and to a very slight extent to friction of air in admission. In this way we are able to account for 23 per cent. of the loss, the remainder being due to defective construction of the bottom chamber, whereby a considerable quantity of air escaped which had been admitted and measured by an anemometer. This loss of air was computed at the time of trial to be nearly 20 per cent. This agrees very closely with loss of energy not accounted for in the author's calculations.

From the subjoined table of losses we are able to understand that a very considerable improvement would be made by increasing the velocity of the downward water, limiting that rate by consideration of the fact that the frictional losses increase as the square of the velocity. Furthermore, by enlarging the diameter of the headpiece, so as to allow a greater number of large air pipes and a lesser number of branch pipes, in order that the latter may be more equally submerged, the efficiency of the apparatus would be increased.

One feature in this system might be here noted, namely, that notwithstanding that the air is compressed by the weight of the water and in actual contact with it, the air so compressed is delivered in the receiver and thence to the transmission pipe drier than when drawn in from the atmosphere. At first sight this would seem impossible, but it is well known that in a high temperature moisture is held longer in the air than in a lower temperature. Hence the contact of the air globules with the cold water keeps down the temperature usually caused by the compression of air, and the atmospheric moisture held in the globules condenses, as it were, on the walls of these globules; and at the point of separation the air and water are absolutely separated, leaving the air ready for distribution at the same temperature as the water it has just left, and drier than when first taken in through the small air pipes.

The compression of air isothermally consumes far less energy than when it is adiabatically compressed, for the consequent rise in temperature in the latter case is invariably lost in transmission. It is a well known fact that a given space will hold a weight of water-vapour greater or less according as the temperature is high or low. If at any given temperature a space is saturated with vapour, when the vapour is compressed isothermally into a smaller space a portion of it will be condensed. Where air is compressed mechanically it is heated, and the water vapour contained is not condensed because of the rise in temperature. When, however, the air passes through the cool transmission pipe condensation takes place. Should condensation not occur in the transmission pipe, on account of insufficient cooling, it takes place at the exhaust of the motor because of the great fall in temperature due to the work done by the expanding air, thereby filling the exhaust with ice.

Where compression of air is effected by water, as in the system considered in this paper, condensation takes place on the walls of the bubble, and so can neither take place in the transmission pipe nor at the exhaust, even when the temperature is very low. The compressed air delivered is of the same temperature as the water compressing it, and in the Canadian plant its volume is about two-ninths of that at atmospheric pressure. Hence the air after its expansion in the motor will not contain sufficient vapour to saturate it at even the greatly reduced temperature. By a test made on 50 cubic feet of air, delivered by the compressor while in full operation, it was ascertained that the air when expanded to atmospheric pressure contained one-fifth of the amount of vapour usually found in the atmosphere during fine weather, or about 14 per cent of saturation.

The advantages of this mode of compressing air may be summarised as follows:—

(1) The compression takes place isothermally.
(2) The initial outlay, repairs, and working expenses, are less than by other means.
(3) It is suitable for adoption in the case of low water-falls.

The author is of opinion that such merits far outweigh the objection of sinking a shaft (for to a miner this is a trifle), even though it may be necessary to line the same in order to keep out the water. The possibility of an extended application of this means of utilising small falls, and even tidal powers, the author thinks will justify the present paper, and will form sufficient grounds for a discussion on the subject.

DISCUSSION.

The President said that Prof. Umney came before them that evening as no stranger. Two years ago he read a very interesting paper before the Society on hydraulic lifts. It must certainly be taken as a compliment to the Society that the author had chosen to deliver his paper on the present very interesting subject to the Society in preference to any of the other English societies this year. The subject was certainly one of importance, not only for mining but for other purposes. Compressed air had been in use for such purposes as lifting sewage and for working motors. In fact, compressed air was used largely in Paris for motors at the present time. In working out the subject of the paper, both Prof. Taylor and Prof. Umney had evidently had in mind the *raison d'être* of civil engineering, which was the conversion of the sources of power in nature to the use and service of man. Prof. Umney had, he thought, shown the meeting conclusively that a very useful power could be obtained simply by compressing air by means of the direct action of water. He would ask the meeting to accord a vote of thanks to Prof. Umney for his interesting communication.

The vote of thanks was accorded unanimously.

Mr. W. SCHÖNHEYDER said he thought the paper was a most interesting one. The apparatus which had been described was entirely novel to him. It seemed most ingenious, for in the apparatus there was practically not a single moving part. The author had stated in the beginning of the paper that this was the first and only apparatus in which air was compressed isothermally. That, however, was an error, for some few years ago he (the speaker) conducted a series of experiments on an air-compressing machine invented by Mr. Pearsall, and in that machine there was certainly isothermal compression. It was an apparatus with very few moving parts, and might be styled a kind of hydraulic ram. It could be made of almost any size, and its efficiency was very high. It appeared to him that an apparatus of the kind now described required a very great deal of making, and must entail much expense, and great care must be taken to put it down just at the right place, because it could not be very well shifted afterwards.

Professor W. W. F. PULLEN said that Professor Umney must be congratulated upon having brought before the meeting a paper which was so full of boldness and of novelty. He had described work which had been carried out in America, and which was performed under conditions which were in marked contrast with those attending work of the same nature in this country. In America the waterfalls were, he believed, fairly numerous and large, while in England they were comparatively scarce, and the supply of water was not only small but very intermittent. Further, the local authorities round the waterfalls in this country generally objected to the fall being harnessed, on the ground that such a means of utilising the power diminished the attractiveness of the neighbourhood. For these reasons he judged that it would be rather difficult to introduce an apparatus of this kind into England, although it could be very advantageously worked in America. He wished to ask Professor Umney whether the apparatus could be varied in capacity, something in the same way that a turbine could be varied? For instance, could the apparatus be worked at half power? He should imagine that unless it could be worked at varying powers it would be rather difficult to manage, and would be less efficient in the long run.

The author had stated that the efficiency of the plant had been registered at about 62 per cent. His (Prof. Pullen's) late chief, Professor Elliott, had shown in a paper, read before the South Wales Institute of Engineers, that at about that pressure of air the relative efficiency, taking the isothermal compression as unity, and compressing the air adiabatically in an ordinary air compressor, was about 82 per cent. Taking the efficiency of an ordinary compressor at 82 per cent., and of a turbine at 80 per cent., which was a very reasonable efficiency, the two working together at the pressure mentioned by Professor Umney would come out at about 66 per cent. That was slightly greater than the efficiency which Professor Umney had stated. But at the same time, as Professor Umney had said, there were in the plant, which contained a turbine and an air compressor, a number of parts, sometimes intricate, which required a considerable amount of inspection and repair, and would cause depreciation of plant. It was rather difficult, in looking at the diagrams, to imagine that the shaft could be constructed at a cost less than that of the purchase of a turbine and corresponding air compressor. Professor Umney had mentioned a very interesting point about the dryness of the air which was delivered from the isothermal compressor. There was no doubt at all that a great deal of the moisture in the air was condensed on the surface of the globules of air, and was given up in the downcast pipe. But they all knew that in a steam boiler under any pressure the globules of steam, as they rose from the surface of the water, often carried with them a large amount of moisture, and he should imagine that the globules of air, as they rose from the surface of the water in the air-collecting chamber, would also carry with them a considerable number of particles of water. But at the same time, they found in the large chamber a curious analogy to what they had in the steam engine. They had there a sort of moisture separator, which was a chamber of large sectional area, in which the upward velocity of the air was so small that the particles of moisture had an opportunity of falling down, and so completely, or almost completely, freeing the air of the moisture.

He would also like to know how repairs were carried out in the shaft. He should imagine that all the water had to be pumped out first, and that would cause not only delay but considerable expense. Hence, he should imagine that the difference of expense between the air compressor described in the paper, and of the ordinary mechanical air compressor would not be very great. Mr. Schönheyder had mentioned a point as to which he (Prof. Pullen) also wished to make a remark, and that was that the shaft when it had once been made had no second-hand value. Consequently, the air compressor now under consideration ought really to have a larger percentage of the capital put down to depreciation of plant than the ordinary turbine or mechanical air compressor would require.

A very peculiar feature about the compressor which Prof. Umney had brought forward was, that it was not so advantageous for high falls as for low falls, as the air could not be compressed unless the water in the delivery pipe was at a considerable height above the air chamber. Therefore, he should imagine that the arrangement was not so efficient under all circumstances as a turbine and ordinary compressor. In America, falls of a height of 200 or 300 feet were often met with, and a turbine would use quite 80 per cent. of the energy of the falling water, and a large portion of that could be converted into useful energy through the air compressor. He took it that the same thing could not happen with the compressor which was described in the paper. He thought that this apparatus could be used very economically at a high altitude. In such a case they took in the air in a less dense condition than at the sea level, and, necessarily, if they plotted out the diagram for adiabatic compression and expansion, they would find that the less dense the air was when taken in, the greater was the loss through adiabatic compression. On that account the isothermal air compressor should be very much more efficient for high altitudes than an ordinary mechanical compressor. He desired to record his high appreciation of the paper.

Professor R. H. SMITH said that the paper described an exceedingly ingenious method of compressing air, and he had listened to it with interest. It seemed to give hope that the adoption of the method which had been described would overcome some of the chief difficulties which had been experienced in compressing air efficiently from a mechanical point of view. The chief difficulty was to keep down temperature during the compression. That difficulty had been fought against in every kind of mechanical compressor which was used, both in this country and in America, and every apparatus which he knew of had been unsuccessful in that respect. He did not know the system which had been alluded to by Mr. Schönheyder. So far as his own observation had gone, the best results were, that the temperature at the end of the rise of pressure was about midway between the initial temperature and the temperature which pure adiabatic compression would raise the air to; that was to say, the compression curve lay nearly exactly midway between the adiabatic and the isothermal curve. The present method seemed to him to consist simply in compressing the air in contact with a great excess of water, and very thoroughly mixed with water. He thought that it was very probable that, under such conditions, a very nearly isothermal compression could be achieved.

It was incidentally a curious point, and to him an exceedingly interesting one, that the air came out of the apparatus drier than it went in. That was said to be guaranteed by the results of an accurately and scientifically conducted test. He saw that it was theoretically possible; but practically it could hardly have been expected to be realised, on account of the large entrainment of water with the air and the almost inevitable formation of vapour cloud in the air-collecting chamber, which cloud must have time to sink, as Professor Pullen had mentioned, if the air was to be got really dry. That result, however, seemed to have been accomplished. He thought it was a pity that the author had not stated the cost of the apparatus. The size of the apparatus seemed to be gigantic for the purpose which was to be achieved, and the objection as to sinking the shaft should not be set aside in the way it was set aside in the paper. Shafts could not be sunk in this country for a "mere trifle" which was immaterial to the consideration of the whole cost of plant. Of course, if one found by accident an old disused mining shaft quite close to a suitable waterfall, and if both the shaft and the water were in convenient proximity to the place at which the compressed air was wanted, the cost of the apparatus might come down very considerably.

He would suggest that all that enormous and gigantic construction, which, in this country at any rate, would be extremely expensive, might be avoided by carrying out the same method mechanically with water-pressure pumps. The essence of the whole arrangement was to pump water through a suitable channel, in which at one place there was a high pressure and at another a low pressure, and to entrain air into the stream of water at the place where there was low pressure, and to separate and collect the air in a suitable apparatus at the place where there was high pressure. A current of water through a channel could be obtained at a comparatively small expense of power if the channel was not long, as in a short channel the frictional resistance was small. Enormously different pressures could be obtained in the course of the channel by variations of the section. If they adopted the injector or ejector principle, and a narrowing down of the channel took place so as to produce very high velocity, and if suitable cones were used for the entrainment of air, the mixture of air and water which was desired would, he supposed, be obtained. The illustrations connected with the paper did not show by any means the best imaginable method of mixing air with the inflowing water.

Mr. H. D. Pearsall said that the subject of the paper was one with which he was somewhat familiar. He should have certainly thought it necessary to make some protest against the remark of the author, that isothermal compression was a new thing, if that point had not been already referred to by other speakers. He was certainly surprised that Professor Umney should be unaware of such machinery, as it had been described a few years ago in the most conspicuous place with regard to engineering methods, namely, the 'Proceedings of the Institution of Civil Engineers.' Machines of the type referred to had been tested, and found to give an actual net efficiency of 85 per cent. in compressing air, and the air had been compressed with absolutely no change in temperature which could be detected by registering thermometers. The machine described by the author was one of a very old type, and he did not see that the particular one which had been mentioned in the paper was substantially better in its results than Mr. Frizell's machine of twenty years ago. The average of the tests given in the paper came out at only 55 per cent., and one test was as low as 50 per cent., and, unless he had made a mistake in checking the calculations given, even that figure was a little above the actual fact.

The chief interest in the paper seemed, therefore, to lie in the question whether the author's expectation as to further improvement was justified or not. The paper contained the very remarkable statement that 20 per cent. of the gross power of the engine was lost, owing to the defective construction of the air chamber or air vessel, and it was said that the loss was measured by an anemometer. He thought that there must be some mistake about the statement. They might get considerable light upon the possibilities of machinery of this class by considering another class of machinery, which was widely discussed in the United States three or four years ago, namely, air lift pumps. These were on precisely the same principle as the machine compressor, but, instead of water flowing through a pipe and compressing air, the compressed air was led to the bottom of an inverted syphon and the air mixed with the water in the rising limb of the syphon, so that the mixture of air and water made a column in that limb lighter than the column in the other limb, and thus started a current through the syphon and so raised the water. The process was exactly the converse of that described in the paper. These pumps had been tested and reported on by Professor Randall and Mr. Behr, and other well-known engineers in America. The latest result, dated last February, was that the maximum efficiency which they had been able to get with the air-lift pumps was only 24 per cent. That rather startling result was arrived at at the City Waterworks, Rockford, Illinois. The contractors guaranteed a certain delivery of water, and they put up a plant under their guarantee in September 1893. The result fell very far below the guarantee, and they had ever since been experimenting, altering, and improving, but the 24 per cent. result of last February was apparently the best that they now hoped for. Exactly the same claims were made for the air-lift pumps as for the compressor, and by the same people—by Mr. Frizell particularly, and Professor Randall. They figured out a theoretical efficiency of 70, 80, or 90 per cent., and it was admitted that the elements of loss in the two kinds of plant must be practically the same.

There was a third way of considering the question of the probable efficiency of this kind of plant. He thought that it was quite clear that some of the figures which Prof. Umney had given as the probable amount of loss were very much underestimated. Prof. Umney spoke of the head due to the frictional resistance in the down shaft, and he calculated it merely on the mean velocity of the fluid in the pipe, but it was perfectly obvious that, if the bubbles travelled down at a less velocity than the water travelled down, they were virtually passing through the water with a certain velocity, and, though such velocity might not be very great, yet it was obvious that, in consequence of the enormous and very irregular surface which the bubbles offered to the fluid, they would create a frictional resistance of large amount which could not be at all estimated unless the size of the bubbles was known, and perhaps not even then. Such resistance was, however, probably many times that of the friction of the fluid against the sides of the pipe. That resistance, however, Prof. Umney had entirely omitted, and so did Mr. Frizell. Notwithstanding that omission, the loss which Prof. Umney did take into account he had calculated out to the minute extent of the hundredth part of an inch.

But, besides the question of rightly estimating known losses, the central question of all machines of the class under notice, both air-lift pumps and compressors, was whether water could be impregnated with sufficient air? It was easy, of course, to get water to hold a certain quantity of air, but the quantity that had to be held in order to produce good efficiency in machines of that class was enormous. Even in the present case air was mixed with water in the proportion of 1 to 4, and if a greater efficiency was to be obtained that proportion must be largely increased. Prof. Umney had given no facts to show that the increase was possible, and the results of the working of the air-lift pump appeared to be extremely strong evidence that it was not. Prof. Umney quite rightly stated that the velocity of the air ascent would increase with the size of the bubble, and the more air there was in the water the quicker the bubbles would aggregate together and make big bubbles, and therefore the more slip there would be. If there was more slip the quantity of air had to be still further increased in proportion to the slip. Moreover, suppose that it was possible to get the water to hold more air, it was even then by no means certain that it would increase the efficiency, for they would be between the horns of a dilemma. If they increased the number of bubbles they would greatly increase the frictional resistance, but if they increased the size of the bubbles they would increase the slip so that there would be a loss of power, either by frictional resistance or by slip.

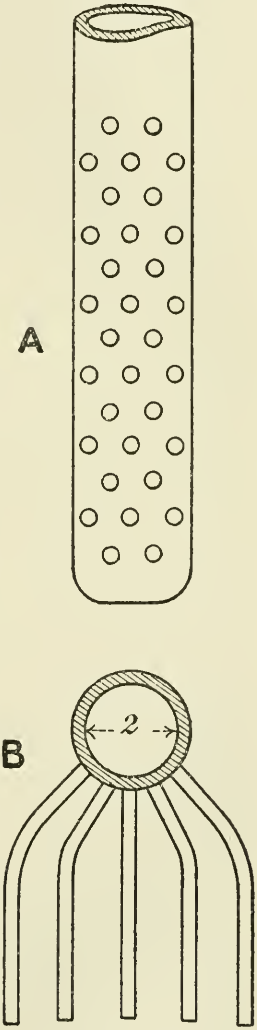
That was not merely a theoretical objection. It was suggested by the tests made of the Pöhle, or air-lift pump, at Rockford, Illinois. The pumps actually gave their best result when the air nozzles, which were specially devised for introducing small bubbles into the water, were removed. In fact, one of the pumps was observed to be giving better results than before, and on examination the reason was found to be that the nozzle had accidentally fallen off. The difference was not very great, but it was in favour of the pipe without the nozzle. That was a very interesting fact from another point of view, because it seemed to confirm what he had said before about the enormous frictional resistance of the bubbles. The fact that when the bubbles were bigger the pump worked more effectively, could only be accounted for by the fact that the big bubbles gave less frictional resistance, and so gave more power to be used in the work which had to be done.

He would ask Prof. Umney to give in his reply a little more information on one or two points. He wished to know what coefficient the author used, and whether any actual experiments were made with the apparatus itself to determine what the actual coefficient was with those particular pipes, and so on; also whether he had any data as to the coefficient of friction of the mixture of air and water as distinguished from ordinary water? Again, how much regulation did the machine require? Did the quantity of water which entered vary? Did the author know anything about the measurement of the air by an anemometer, and could he say how it was done? To measure air by an anemometer was usually a very unreliable method, and he should very much like to know the details. It would be very interesting to know also how the measurements of the water were made. Then as to the size of the bubbles. The author assumed that he knew what the size of the bubbles was, and what amount of slip there was. He (Mr. Pearsall) should very much like to know what experimental evidence the author had for those figures. The author mentioned "available head." As the available head varied something like 5 per cent., he should like to know what the author meant by "available head."

Mr. F. E. Duckham said that he was afraid that he could add very little to what had been already said. His experience had been more with ordinary compressors and exhausters, which could be used at factories and in docks, and not with such an apparatus as had been brought before the Meeting; but he had been very much interested in the paper. Following what had been said by Mr. Pearsall as to the air-lift pump, he might mention that some time ago he came across a pamphlet, dated about 1840, on spray pumps, in which an inverted syphon, or U pipe, was also employed. Air was forced down one leg, and water, gravitating through small holes at the bottom bend, was blown up the other leg and discharged as spray. The arrangement invited attention, and he followed its history in the mechanical journals of the day. The reports and the correspondence thereon varied considerably respecting the performances and merits of the apparatus, but it was ultimately abandoned.

Mr. J. Bernays said that the subject was an interesting one, and he thought that they ought not to throw too much cold water on the process which had been described, as it was rather novel and opened up a new prospect for an additional method of using water power. He should have liked to see somewhat clearer drawings. He could not clearly see how the inlet pipes acted, and they did not show at all clearly how the air was to get in and mix with the water. One very great peculiarity which struck him was, that in the down pipe the air bubbles naturally got more and more compressed, and consequently they left a larger and larger space for the water around them in the pipe as they got down. But the pipe seemed to be made larger instead of smaller at the lower end, so that a certain loss of water appeared to be incurred which could be avoided if the pipe was made smaller instead of larger at the lower end. He quite agreed with what had been said about the size of the apparatus, and he was very much inclined to doubt whether an apparatus of that kind could be cheaper than a small turbine and air compressor for the same amount of work. The apparatus was, of course, more simple than a turbine, because there were no moving parts. He had been struck with the same idea as Professor Smith with regard to the difference of fall which was required to work the apparatus. A small injector might produce exactly the same speed of water through the pipe, and push the air forward with the same force as was now done by means of the great shaft, and one might almost get rid of the shaft and do the work on the surface of the ground.

Mr. Arthur Rigg said that the compression of air by the direct action of water seemed to him to be a system for getting rid of a large amount of machinery—always an extremely desirable object. When there was a waterfall of ample power, then if 25 per cent. of the power could be got out of it by means of imperfect machinery, even that result would be very good. Too much, often, was made of mere efficiency, whereas simplicity and durability were frequently of more value. He did not see that it was the slightest reproach to the machine which had been described if they could only get 25 per cent. efficiency out of it—instead of more at the cost of more expensive and complex machinery—if they could only get plenty of power to do the work without cost. One of the most interesting points in the paper seemed to be the drying power of the water upon the air passing through it, an operation which had been already utilised for a corresponding purpose.



Professor UMNEY, in rising to reply to the discussion, said he first wished to acknowledge his indebtedness to his colleague, Professor Nicolson, who, as consulting engineer to the Taylor Hydraulic Company, had given him much help in preparing his paper. The Professor then observed that the inlet tube appeared to have been a source of difficulty with some speakers during the discussion. He was sorry he had not shown a diagram of it, but he would sketch it on the blackboard. (The annexed illustration shows the tube. A is an elevation of a 2-inch air pipe with the branch tubes removed; B being a sectional plan of the pipe showing the $\frac{3}{8}$-inch branch tubes.)

Continuing his reply, Professor Umney observed that Mr. Schönheyder had expressed a fear that the removal of the plant, when it had been once fixed in the shaft, would be a cause of trouble. There would not, however, be much difficulty in pulling up the tube inside the shaft should any repairs become necessary—a rather unlikely thing, as a slight leak would not make very much difference. Boilersmiths were accustomed to make thoroughly good and reliable joints, and so he did not think that it was reasonable to suppose that occasions for repairs would occur once in ten years, when the shaft would have to be pumped out. As to providing a shaft, of course it was not to be expected that disused coal pits were likely to be found available where the apparatus was wanted, but it was not a hard matter to sink a pit of a reasonable size. A shaft would not need to be more than 150 feet deep, and if it was made of a diameter of 6 or 10 feet, there would be every facility for getting the material out of the shaft and smashing up the rock.

Prof. Pullen did not seem to think that the apparatus would be cheap. The cost of a turbine and air compressor in Canada had been found to be about 60 dollars, or 12*l*., per horse-power, as compared with 9*l*. for the machine described in the paper. Those prices were founded on the current rate of wages over there for well sinking.

The question was asked whether it was possible to use the apparatus at half power, and his reply was that the quantity of water which was allowed to flow down could be regulated by the screw at the top. The screw would reduce constantly the amount of water carried down, and similarly the amount of air compressed. It was a great advantage that the apparatus would go on working without requiring any fancy governors to cut off the pressure.

Mr. Rigg had pointed out that the water cost nothing, and that therefore they need not be very particular about putting in a big plant. Sixty-six per cent. was a very reasonable figure for the total efficiency of the apparatus. As to the price, he could not very well state it, for the plant described was only experimental, and in such there was usually a great deal of money expended for various purposes which did not arise again.

It had been said that one objection to the apparatus was that it interfered with the appearance of the natural scenery, and that people objected to ugly-looking machines. But surely there was nothing objectionable in the appearance of the plant which would be required in a case of this kind. It would not be like a great chimney erected in a country place. As to the secondhand value, he would ask Prof. Pullen whether he would be likely to get much for a secondhand compressor. He did not think that much would be got for such an apparatus secondhand any more than for any secondhand direct-acting air compressor.

Mr. Pearsall did not seem to appreciate the fact that the figures were given to the thousandth part. The reason was that they were worked on a slide rule, and it was as easy to put down the last figure under such circumstances as any other. Had the calculations been made in any other way they would not have been carried to such an extreme point. The coefficient of friction which he took was a practical one, namely, ·0075. That, for the coefficient of a tube which had no lap joints, he thought at the time to be a very hard and harsh treatment of the machine. Mr. Pearsall was anxious to know about the measurement of the air by an anemometer. The anemometer used for the purpose was one specially graduated. At the University they had an observatory and every reasonable appliance for testing their instruments. The instrument was tested before starting, and was placed at the top of the tubes, so that the amount of air going into the tubes was measured. At the other end, namely, at the end of the pipe where the regulating valve was, an arrangement was made so that the tube should exhaust straight through another anemometer which had been similarly carefully examined and tested. Thus there was a means of measuring the air that went in and also that which came out. Some of the air disappeared, going up the side through the tail race. It was not lost through any leakage of any kind whatever, in the sense to which Mr. Pearsall referred; but its disappearance was due to the fact that the aprons at the bottom did not sufficiently allow the air to separate from the water.

The downward pipe was enlarged out at the bottom in order that the velocity of the current of water should be decreased; and, furthermore, at the bottom, where the air separated from the water, it passed into a chamber 17 feet in diameter, in order that the velocity might be as near nothing as possible. By that means the air had a fair chance of rising. But on the other hand, the size of the chamber proved too small at the bottom, so that sufficient aprons could not be fixed into it to stop the water from rushing through, and consequently some of the air was not caught. Mr. Pearsall had made a great point of the fact that the velocity of the rising bubbles was in proportion to their size, and he pointed out that if many were got in they were going to amalgamate and make a big bubble, and that then they would rise quickly. But the bubbles went in separately, and as soon as they began to get a little way down they became smaller and smaller. In fact, when they reached the bottom they were less than a quarter of an inch in diameter, although three-eighths of an inch at admission. Therefore, the space occupied by the bubbles was very much less, and hence they had far more room between them, and their chances of joining together were no greater at the bottom than at the top—in fact, less. The water discharged was measured over a weir, which was constructed with a sharp-edged notch, and a levelled stake was driven in some distance back, so that the amount of contraction should not affect the careful measurements made. The variation in head was due to the fact that the water from which the supply was taken, which was a canal, varied considerably from one time of day to another, because there were other mills on the stream. For that reason there was a fluctuation of about 5 per cent. He was sorry to hear that the calculations were not quite agreeable to Mr. Pearsall, but he believed that if he (Mr. Pearsall) would look at them again he would see that he might have slipped in some way.

It might be interesting to add that the use to which the plant was put at the cotton mill was as follows. The mill formerly had steam engines and turbines working to supply some 600 or 700 horse-power, and that was not sufficient. The boilers were weak, and so the engines would not do enough work, and consequently it was decided to put in additional turbines. The inventor, however, persuaded the owners to have the compressed air, by pointing out that they could then use their old engines without any alterations to existing arrangements as would be required, since each machine had its own engine.

CORRESPONDENCE.

Communicated by Mr. F. E. Duckham: Following Professor Umney's concluding remarks as to the loss of 20 per cent. air, assumed to be "due to the defective construction of the bottom chamber," I beg to offer the following explanation. When water and air are in intimate contact with water under pressure, water absorbs air at about ·16 per cent. volume per lb. pressure per square inch, and retains this until the pressure is removed. A familiar example exists in bottled aërated water. At the trial (III.), to which the Professor specially refers, the quantity of water was 4005 feet per minute, the pressure in bottom chamber 52 lb. per square inch, and the air delivered 1095 cubic feet, or say = 1370 feet admitted; therefore, in addition to the air in bubbles which found their way into the air pressure pipes there would, by this calculation, be 4005 × 52 × ·16 × ·01 = 333 feet in solution, or 25 per cent. of the 1370 feet admitted air. Allowing for imperfect absorption, this seems just to account for the 20 per cent. loss.

Communicated by Mr. Rhys Jenkins: It has occurred to me that at last night's discussion on Professor Umney's paper, a reference to another American plant in which compressed air is produced by water power might have been of interest for purposes of comparison. I allude to the plant of the North Star Mining Company, Grass Valley, California, which will be found described in a paper by Mr. A. de Windt Foote, in the 'Proceedings of the American Society of Civil Engineers' for 1896. This plant comprises a Pelton wheel 18 feet 6 inches diameter, which drives directly a compound compressor with cylinders $\frac{18 \times 10}{24}$, producing air at a pressure of 90 to 100 lbs. Of the 304 horse-power in the water, 203 are exerted in the motors at the mine, but three dollars' worth of wood is used per day for reheating. Adding three dollars' worth of water to that actually consumed, the efficiency of the entire plant, water wheel, compressors, pipe line and motors, becomes something over 60 per cent.

Communicated by Mr. J. P. Frizell: I was very glad to receive a copy of your paper on 'The Compression of Air by the Direct Action of Water,' with special reference to the plant in operation at the outlet of Magog Lake, in Canada. As regards Mr. Taylor's mode of applying the principle, it does not appear to me that he has made any improvement upon the method adopted by me in my experiments at Minneapolis in 1880. No ingenious arrangement of pipes and passages is called for in the process of impregnating the water with air. All that is necessary is, to throw the water into commotion. Any one can convince himself of this fact by intelligently observing the pouring of a glass of water at the table. A slight fall in a running stream, the breaking of waves, &c., are examples. It is interesting in this connection to observe the working of a steamer's screw propeller. It thickly impregnates the water with air-bubbles to the depth of probably 50 feet, so that, on cessation of the working, many seconds elapse before the water is cleared.

My patent of 1878 contemplated the use of a syphon to suck in air, but in the experiments this was immediately abandoned on observing the superior efficiency of the simpler method. This method is attended with a certain automatic principle of regulation which a judicious engineer might readily take advantage of. If the quantity of air introduced in this manner is less than the descending column of water can carry, the surface falls, the fall and consequent commotion at the entrance increases, and a greater quantity of air is taken in. If the descending column is overloaded with air, the surface rises, the commotion diminishes and less air enters.

The counterpart of the method of compressing air by introducing it at the entrance to the descending column is the method of raising water by injecting compressed air at the base of the ascending column. This method was patented by me in 1880, and has been extensively applied by the Pöhle Air Lift Company to the raising of water from artesian wells. The method you refer to as having been used in Spain long ago, was it not the tronc for operating the Catalan forge? This has little in common with the method under discussion. The essential difference is this:—With the tronc you could obtain no greater pressure than that due to the head. With this method the pressure obtainable is in no way related to the head.

RESULTS OF THE TRIAL OF TAYLOR'S HYDRAULIC AIR COMPRESSOR.

	i	ii	iii	iv	v	vi	?
Water discharged in cub. ft. per min.	6122	5504	4005	7662	6312	7494	4000
Available head in feet	21·4	21·9	22·3	21·1	21·7	21·2	22·0
Available horse power	247·7	228·0	168·9	305·9	260·0	299·8	
Air delivered at atmos. p. in cub. ft. per min.	1377	1363	1095	1616	1506	1560	1250
Pressure of air in compressor	52	52	52	52	52	52	52
Actual horse power of compressor	132·5	131·0	105·3	155·4	144·8	150·2	
Efficiency of compressor	53·5	57·5	62·4	50·8	55·7	50·1	75·12
Temperature of external air—Aug., '96	79	83	80	75	77	75	
,, ,, water	75·2	75·5	75·6	80	80	80	
,, ,, compressed air	75·2	75·5	75·6	80	80	80	
Ratio of Water to Air	4·45	4·04	3·66	4·75	4·20	4·80	3·2
Mean velocity of water down shaft in ft. per sec.	10·89	9·89	6·98	13·50	11·28	12·62	7·42
,, ,, rising bubbles $=1·5\sqrt{d''}$	·81	·81	·81	·81	·81	·81	·81
% Loss due to air bubles rising	7·48	8·14	11·67	6·03	7·22	6·45	10·63
Head equiv. to velocity lost at bottom	·609	·499	·266	·948	·651	·906	·270
,, ,, ,, at entrance	·576	·478	·241	·893	·620	·758	·279
,, ,, frict. resist. in down shaft	2·117	1·754	·874	3·245	2·278	2·893	1·749
,, ,, ,, ,, up shaft	·038	·031	·021	·061	·041	·073	·016
% Loss due to above hyd. resist., etc.	15·61	12·61	6·29	24·38	16 54	21·73	10·97
Total % losses calculated	23·09	20·75	17·96	30·41	23·76	28·18	21·60
,, ,, ,, unaccounted for	23·41	21·75	19·64	20·39	20·54	21·72	3 28

The final column is calculated so as to show how readily the efficiency would be raised by the more thorough impregnation of the water.

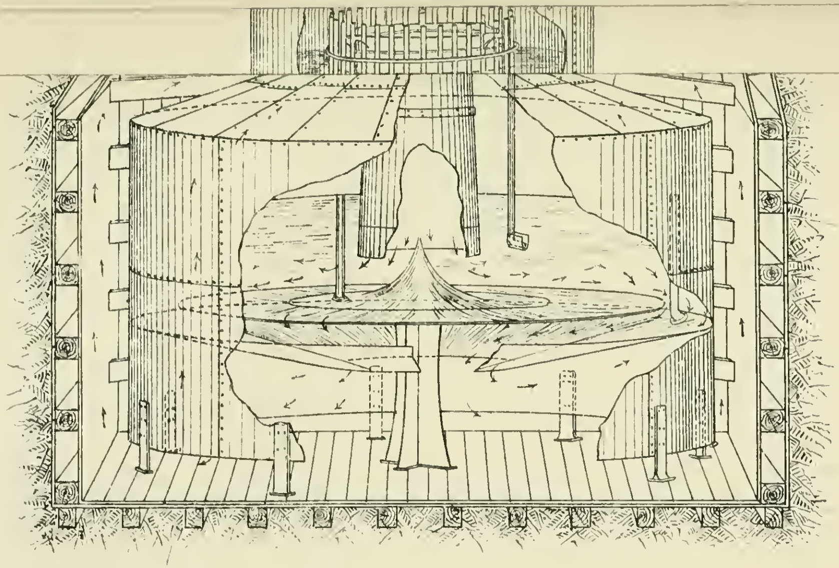


Fig. 5.

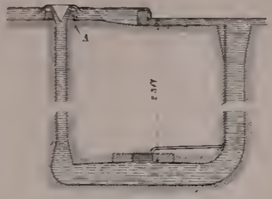


Fig. 1

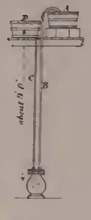


Fig. 2.

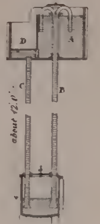


Fig. 3

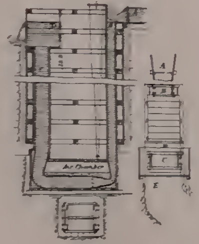
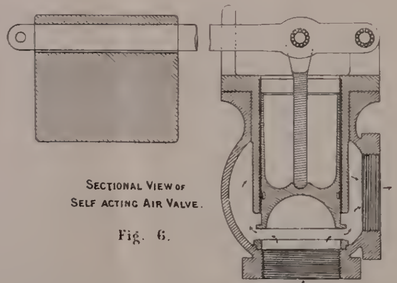


Fig. 4.



SECTIONAL VIEW OF
SELF ACTING AIR VALVE.

Fig. 6.

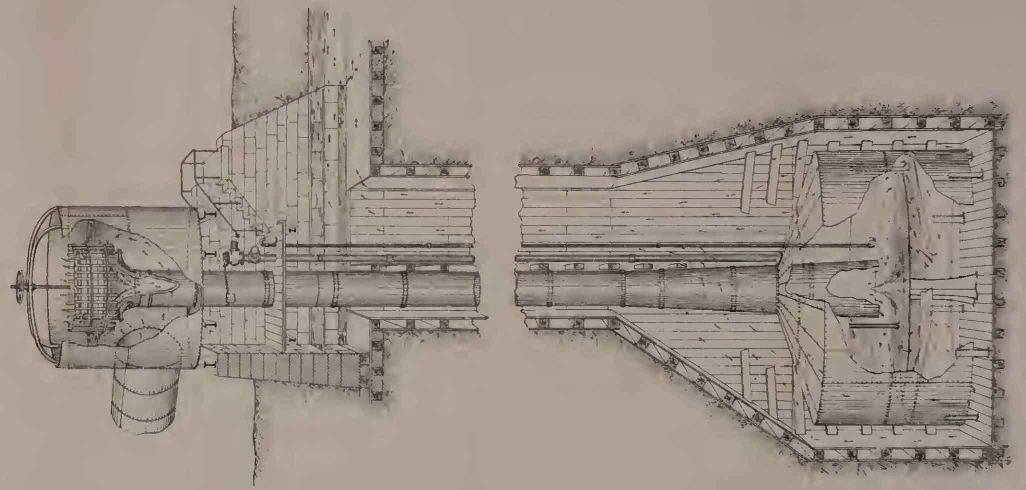


Fig. 5

E. & F. N. Spon Ltd London

VACATION VISITS.

The usual Vacation Visits were made during the summer and autumn of 1897. They were three in number, and the first, on June 17, was to the London section of the Manchester, Sheffield and Lincolnshire (Extension to London) Works. The second, on July 20, was to the works of Messrs. Easton, Anderson and Goulden at Erith. The third, on October 6, was to the Royal Arsenal, Woolwich.

The following are general descriptions of the several works:—

THE MANCHESTER, SHEFFIELD AND LINCOLNSHIRE RAILWAY WORKS.

The works comprise the metropolitan division of the Manchester, Sheffield and Lincolnshire Railway (now called the Great Central Railway) extension to London. The trains of the company will run from the point where their new main line joins the Metropolitan Railway at Quainton Road, over the rails of the latter company to Harrow, from which place two new main lines for the exclusive use of the Manchester, Sheffield and Lincolnshire Railway are being constructed by the Metropolitan Railway Company, adjoining their own line, to a point near Finchley Road Station, at which place the work is taken up by the Manchester, Sheffield and Lincolnshire Railway, and is the property of that company. At Neasden, which the new line of the Metropolitan Company passes, the Manchester, Sheffield and Lincolnshire Company are laying out a large sorting yard and engine house, &c., for the accommodation of the London working. From Finchley Road Station the new line runs southerly by means of covered way, 26 feet 4 inches in width, and at some points quite close to the existing line of the Metropolitan Railway, until it reaches the London and North-Western Railway, which is crossed between the Loudoun Road Station and the westerly mouth of the Primrose Hill tunnel by a steel girder bridge of three spans, and then runs into covered way again at the northerly side of the Alexandra Road, continuing either in covered way or tunnel until it emerges into a large opening lying between Circus Road and Wellington Place. It again passes by means of a covered way, constructed with three arches, one of 40 feet and the other two of 26 feet 4 inches each, the whole accommodating seven lines of rails, under Wellington Place, Lord's Cricket Ground, and St. John's Wood Road. All the retaining walls, side walls, and arches of the covered way and tunnel are faced with blue brindle brick, and present a solid and massive appearance.

The work under Lord's Cricket Ground had to be done during the winter months, and the visit showed that no time had been lost, for the turf over the covered way was already green and in good condition. As fast as the arches were turned the dumpling under them was excavated and lifted through openings left for the purpose, and the filling over the arches followed the brickwork quickly, work being continued day and night.

The Regent's Canal is crossed by a large steel bridge, the openings for the passenger main lines being spanned by through girders; while that portion for the goods and coal lines has been made a deck bridge, and covered with Hobson's steel flooring so that rails can be laid, and points and crossings laid in at any part irrespective of the girders. The Regent's Canal has been widened, and a retaining wall built on the south side to form a lay-by for barges interchanging traffic with the railway, and a transfer shed and several cranes will be placed on the railway wharf. Just after crossing the canal a separate pair of lines diverge and run west to Grove Road, under which they pass to an extensive coal depôt which occupies an area of about 20 acres.

The goods warehouse, which will be 385 feet in length by 255 feet in width and will have five floors, is situate on the former site of Alpha Road, and between it and a new road to the south of it, which extends from Grove Road to Park Road, and which will cross over all the lines of way leading into the passenger station. This road will be 60 feet in width, and is paved with hard wood blocks of Jarrah timber. Another new road leaves this at right angles near the new vicarage and schools of St Paul's Church, which have had to be rebuilt, and runs alongside the site of the new passenger station and to the Marylebone Road.

The passenger station will have a frontage of 325 feet on what was formerly the south side of Harewood Square. It will contain the booking office, restaurant, and the usual waiting and other rooms on the ground floor, and the general offices of the company on the first floor, and will be of red brick. In front of the office there will be a promenade 100 feet in width, and extending the whole length of the frontage, and from this promenade access will be had to the departure and arrival platforms, which, for the present, are limited to a width of 158 feet on the easterly side, the rest of the space to the west being reserved for future extensions. The platforms and cab rank—which latter is entered from the bridge over the lines at the north end of the station—will extend to that bridge, and will have a length of 1000 feet, but the roofing will at present only extend northwards for half that distance. The spans of the roof will be two of 50 feet, one of 40 feet, and a temporary span of 18 feet, and will be carried on columns and arched lattice spans running north and south. In the covered way, tunnels, and retaining walls, completed at the time of the visit, strength and massiveness are the principal characteristics, and there has been no superfluous expenditure upon ornamentation.

There are an average number of 3000 men employed upon the works, which are let under contract with the company to Mr. J. T. Firbank, M.P. Messrs. Sir Douglas and Francis Fox are the engineers-in-chief. In front of the station and between it and the Marylebone Road, the Grand Central Hotel of the Gordon Hotels Company, to be worked in connection with the railway, was being erected. It will consist of a building occupying a block of land 313 feet from north to south and 233 feet in average width from east to west. It will occupy four sides of a central quadrangle, which will be roofed over in the manner of several Continental hotels, and will form a handsome front for the station, to which access will be had by two new wide streets, east and west respectively of the hotel. Colonel Edis is the architect of the hotel.

THE ERITH IRONWORKS.

The Erith Ironworks were commenced in 1864 by the firm of Easton, Amos and Anderson, and were laid out by Sir William Anderson, then a member of the firm, and now Director-General of Ordnance Factories. Designed at first as an off-shoot from the principal works at the Grove, Southwark, gradual extensions were carried out from time to time, until in 1873 the Grove Works were finally closed, and the machinery and tools moved down to Erith. The works stand on a plot of ground about 17 acres in extent, and have a frontage of about 800 feet to the River Thames, and the various shops are arranged side by side, the general direction being such as to allow of the shop travellers working out on a gantry over barges lying in the river. A railway siding extends from the South Eastern Railway into the works, so that easy communication both by water and rail is ensured. The works are entered through the offices, which are placed at the south-west corner of the property, and consist of a general office, with manager's and other rooms on the ground floor. An extensive drawing office occupies nearly the whole of the first floor, the remainder being taken up by estimating and electrical offices; above is a photographic room. The various shops lie between the offices and the river. Commencing from the west side there are covered stores for stock, 95 feet by 43 feet, and sheds for patterns covering an area of 150 feet by 90 feet. Next to these lie a pattern shop 100 feet by 50 feet, with a packing store at one end, and an electrical shop in two bays with a store close by. The dimensions of the electrical shop are 150 feet by 100 feet, and room is left at the river end for extensions.

East of these shops is a large open yard, and again east of this is the main building, consisting of six equal spans of 43 feet by 600 feet. The two western spans are occupied by an iron foundry 240 feet long, a brass foundry, and smiths' shop. The next two spans are appropriated to machine and erecting shops, the roof of the latter being carried up so as to allow for the erection of lofty engines, the traveller rails being 39 feet above floor level. The two bays next to these are devoted to boiler and bridge building. Beyond this is another extensive yard, in which is a gantry used for the erection of caissons and other large work not easily dealt with in the shops. Beyond this is a field which is utilised as a ground for testing gun carriages, and is provided with butts, and other accessories. There is a large dining hall for the accommodation of the workmen. The works are well provided with railway tracks, and materials can be transferred from one department to another at a low cost.

One of the principal businesses in which the company is engaged is pumping machinery. Formerly they used to make large numbers of beam engines for this purpose. Of late years they have been developing the direct-acting inverted triple expansion type, a notable installation being at the new waterworks at Leicester, where there are three such engines of large size. Horizontal three-throw pumps specially suitable for mine pumping are largely made for being driven by electric motors or other means. Centrifugal pumps were made on Mr. Appold's principle for the Great Exhibition of 1851, and the manufacture of all sizes has been continued ever since. Another small though important branch of this trade is hydraulic rams, which were introduced by the founder of the company into this country about 1827, since which time immense numbers have been made and fixed. Of late years a new and very efficient pattern has been adopted as a result of much experimenting.

Cranes and lifting machinery, especially of large sizes, for hydraulic, electric, or steam power, are manufactured at Erith. Among notable examples may be mentioned the 160-ton shearlegs for Sydney Harbour, a 150-ton travelling crane for Woolwich Arsenal, and a 150-ton travelling hydraulic crane for Shoeburyness. Steam engines for driving purposes, and air compressors are among the products. The company have just brought out a new Corliss gear, the invention of their chief draughtsman, Mr. J. Bjornstad, which is very simple and efficient. They have also introduced a new high-speed engine (called the "Erith" engine), chiefly for direct driving of dynamos, which promises to have a good future before it. A special branch of industry which has provided a good deal of work in the last few years is the machinery for the manufacture of cordite. A large quantity of the machinery in use by the Government has been made by the company, or else at the Royal Arsenal from their designs, and all, or very nearly all, that used by private manufacturers in this country and abroad. An ingenious machine, invented some years ago by Sir William Anderson, for winding the wire on wire guns, is made by the company, and a number have been supplied to those engaged in this branch of manufacture. It is very simple and compact, and yet enables the stress on the wire to be regulated and controlled with the greatest nicety. The Niagara Pulveriser is a different class of machine from any of the foregoing. As its name implies it is for the reduction of substances to powder, and can be used for almost any material. It is expected to be much used in the future for crushing quartz in gold mining operations.

Of late years an extensive electrical department has been added to the works, which received an additional impetus when the old company of Easton and Anderson, Limited, was amalgamated with the electrical firm of W. T. Goolden & Co. The principal work in this department is the manufacture of dynamos and motors of all sizes and for both continuous and alternating currents. The newest type of dynamo which is being manufactured has four or more poles and slotted armatures with a special drum winding. The difficulties hitherto experienced with slotted armatures have prevented their adoption in spite of the great advantages they possess, but the company have overcome these difficulties, and their new machine, designed by their electrical engineer, Mr. V. A. Fynn, is an undoubted success. They have also introduced a new alternator possessing many features of interest, which has given remarkably good results in efficiency—and, what is of the greatest importance, is almost noiseless; thus overcoming one of the great drawbacks in the use of alternate current machines, namely, their unpleasant hum.

Electric mining machinery forms a large part of their work. Messrs. W. T. Goolden & Co. were one of the pioneer firms in this branch of industry, and were the introducers of the system of enclosing motors for use in fiery coal mines, thus rendering the adoption of electricity more universal than it would otherwise have been. The special applications have been principally made in the direction of electric pumping, hauling, drilling and coal-cutting. A great number of electric lifts have been made, and several are at present in hand, among them one for the South London Electric Railway, to take the place of one of the existing hydraulic lifts. The system adopted does away with the cumbersome barrel usually employed, besides enabling four ropes to be used to suspend both the cage and the balance weights.

In the boiler department, all kinds of boilers are made, but principally Lancashire and Cornish land boilers. A speciality in this way is the Cornish multitubular boiler specially designed for export, having a maximum of evaporative power combined with a minimum of shipping measurement, but not sacrificing good and economical steam producing properties.

The Royal Arsenal, Woolwich.

The visit to the Royal Arsenal was very well attended, and the visitors were conducted in separate parties over the various departments comprising the Royal Laboratory, the Royal Carriage Department, and the Royal Gun Factories, in each of which they inspected the numerous operations in the following order:—

Royal Laboratory.—(1) Bullet making. Lead squirting. Manufacture of rifle bullets. Manufacture of lead cores and cupro-nickel envelopes for magazine-rifle bullets; assembling and finishing the same. (2) Manufacture of solid drawn brass cartridge cases for quick-firing guns. Drawing, indenting, wending and finishing operations. (3) Manufacture of zinc and brass cartridge cylinders and cases. (4) Manufacture of metal time fuzes. Exhibition of specimens showing various operations. (5) Shell forging. Manufacture of quick-firing shell bodies. (6) Cast-steel shell making. Sand mixing. Core making. Moulding. Casting. Annealing. Grinding, &c.

Royal Carriage Department.—(7) Manufacture of siege, field, quick-firing and machine-gun carriages. Various operations. Exhibition and explanation of finished carriages. (8) General machine operations and work on mountings for heavy ordnance. (9) Band-saw for metal work. (10) Steam saw mills. (11) Tireing gun-carriage wheels. (12) General woodwork in connection with carriages. (13) Small-arm and quick-firing ammunition box making, machine planing, dovetailing, &c. (14) Wheel making. Turning spokes and other copying-lathe work. Making felloes. Pressing wheels together. Saddle-tree making.

Royal Gun Factories.—(15) Oil-hardening hoop for heavy breechloading gun. (16) General operations in connection with heavy breechloading guns. Boring hoops and tubes, rifling, &c. (17) Breech mechanisms. Working models of breech mechanisms of heavy breechloading guns. Examination and explanation of 12-pounder field guns, and of 6-pounder and 4·7-inch quick-firing guns. (18) Wire winding. (19) Manufacture of field and quick-firing guns. (20) Sighting and completion of breechloading guns. (21) Shrinking hoop on to breechloading gun.

This highly interesting visit was brought to a conclusion by an inspection of the extensive harness stores. The officials who were told off to conduct the visitors round the Arsenal were unremitting in their attention, explaining everything which was of interest to the members.

October 4*th*, 1897.

GEORGE MAXWELL LAWFORD, PRESIDENT,
IN THE CHAIR.

FILTER PRESSES FOR SEWAGE SLUDGE.*

BY JAMES CROLL.

IN dealing with the disposal of water-carried sewage in inland districts, the chief consideration is the separation of the water from the solids. On the quantity to be dealt with, and the character of the district, depend mainly the most suitable method to be adopted. Where sufficient land with a suitable soil and subsoil is available, and the situation favourable for irrigation, the sewage is frequently disposed of with advantage for this purpose, thus obviating the necessity for a chemical or mechanical process. When, however, irrigation is not practicable, and precipitation of the solids by means of chemicals is resorted to, the sewage, after being chemically treated, is collected into tanks, designed for the purpose, and allowed to settle. The clarified water is drawn off by means of floating arms and valves, leaving a muddy deposit containing a large percentage of moisture, varying from 90 to 95 per cent. of its bulk. For reducing the moisture in this residue to a condition in which it can be easily handled, various evaporative methods have been adopted, which consist of evaporation by exposure to the atmosphere, or by heat applied. The former in most cases gives rise to a nuisance by polluting the atmosphere of the surrounding district, and a large area of ground is therefore required, while the latter is inadmissible on account of the expense it entails in the operation. The method most commonly adopted is that of separating the water from the solids by an apparatus known as a filter press. This machine is speedy and cleanly in its operation, producing the solid matter in a portable form, is easily manipulated, free from offensive odours, and, as regards cost, it compares favourably with any of the other methods in practical use.

Filter presses are also applicable to other industries where it is necessary to separate water from solids, as in breweries and chemical works. This machine is generally constructed of a number of plates having grooves for drainage on each face, communicating with an outlet at the bottom, and having a passage in the centre for through communication. It is mounted on a frame, and the diaphragms are held apart by means of distance pieces, or rims cast on, thus forming a cell between each two plates. The surfaces of the diaphragms are covered with a filtering medium, which also serves as a jointing material at the rim when the whole has been forced together, and prevents the escape of any of the matter to be operated upon. For closing the press, an apparatus is provided at one end, consisting of one or more screws, acting on a massive plate, called the head or follower. At the opposite end is an inlet valve and pipe, through which the fluid to be treated is introduced under pressure, and it passes through the centre communication of each plate, and is distributed throughout the press. As nothing introduced can find an exit without passing through the filtering medium, on pressure being applied the water is forced through the cloth into the drainage grooves, and is discharged at the outlets at the bottom of the plates. The solids being retained accumulate within the press until the cells are filled. When this is accomplished the filtrate will have ceased to flow. The press is then opened for the removal of the accumulated solids, which are in the form of cake, varying in consistency according to the material treated. In the case of sewage sludge cake (where a small proportion of lime has been added to the sludge) the moisture varies from 50 to 60 per cent. Thus it follows that from 5 to 6 tons of wet sludge at 90 per cent. are reduced to about 1 ton of cake.

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* A Society's Premium was awarded to the author for this paper.

This class of machine has now been in use for a number of years, and is of various design in detail, according to the character of the work to be performed, many improvements having been made which have materially reduced the capital outlay, and added to its efficiency. With slight modifications it can be applied to a variety of purposes; in fact, before any attempt was made to adapt it to the treatment of sewage sludge, it had been in successful operation in sugar refineries, oil-works, breweries, chemical and other works, for many years. The press is usually constructed of cast iron with steel side bars, but in some cases the plates are of wrought iron or gun-metal. Where metal chambers are inadmissible, such as for the filtration of substances acting chemically on metal, wooden plates are found very useful, although they have to be worked at low pressure. As it is intended in this paper to deal with the apparatus as applied to the treatment of sewage sludge only, the details of the different presses and plates in use for other purposes will not be considered.

In adapting the filter press for sewage purposes, the chief difficulty has been in designing a plate of sufficient strength to withstand the pressure on one side only without it being of excessive weight or thickness. Such a plate is necessary in consequence of the frequent stoppages of the central passage between the chambers, by reason of the fibrous matter contained in the sludge attaching itself to the edges of the passage and accumulating (as it readily does) until the passage is completely blocked, thus destroying the equilibrium of pressure on opposite sides of the plates. As a pressure of 90 lb. to the square inch is frequently used on presses with 36 inch plates, and the plates have to be moved by hand twice during each operation of unloading, the impracticability of having a plate of sufficient thickness to withstand such a pressure will be readily understood. To guard against breakage in such cases various devices are in use, notably that in which a series of bosses are cast on the surface of the plates at equal distances, which, when the plates are in position face to face with each other, come in contact and form a series of stays, thus reducing the area of unsupported surface exposed to pressure. (See Figs. 1 and 2.) Another method is that of giving the plate a curved section, as shown in Fig. 3. The convex side being towards the inlet end of the press, additional strength is obtained, offering the necessary resistance when a blockage occurs. In presses of small dimensions, the plates are usually made straight and unsupported. In some cases they are circular in form, and although obviously of greater strength than square plates, they are somewhat wasteful as regards cloth, seeing that an equal length must be cut off the roll for either shape. The square plates give a larger filtering surface than those of the round presses where the diameter equals the breadth and depth of the square.

Fig. 4 shows a section of the flush plate and distance frame type. The distinctive feature of this type is that the rim is flush with the drainage surface of the diaphragm, which may be constructed either of wrought or cast iron. The filtering medium usually employed with the cast-iron plate having a drainage surface is jute or hemp canvas. The wrought-iron plate not being provided with a drainage surface, the canvas is substituted by a thick mat of coir fibre, which, by the arrangement of its strands, forms a number of drainage passages in itself, through which the filtrate passes to the outer edge of the diaphragm, where it is received into channels and conducted to the outlet.

The screw-tightening gear employed on the smaller machines is simply a powerful screw with a capstan wheel or other leverage attached, the screw acting on the centre of the follower. For large machines additional tightening gear is necessary to obtain sufficient pressure for making the joints between the chambers water-tight under pressure, and so avoid the inconvenient leaks and squirting which sometimes occur. One system of opening gear in frequent use consists of moving the follower backward or forward as required, by means of an air cylinder attached to the end of the frame. A screw on each side rod is also provided, by which the final tightening is effected. Movable distance pieces, placed between the screws and the follower, are also provided to allow the necessary space for opening.

The method of introducing the fluid into the press is a matter of considerable importance. Practically, there are but two systems in use for the purpose, viz. the direct forcing system, and the pneumatic or air pressure system. Were it not for the practical difficulties that are met with in pumping a mixture containing large quantities of solids of such a character as sewage sludge, the direct pumping system would undoubtedly be the more economical method, and its simplicity and smaller capital expenditure are points very much in its favour. When this method is adopted, the motive power and the capacity of the pump should be in such proportions as to be capable of working at a varying speed, and equally balanced when the maximum pressure is reached, as a large quantity of sludge is required to be forced into the press at the commencement of the charge, and afterwards gradually diminished as the operation goes on. If the motive power be in excess of the pump capacity, the pressure may rise and cause a breakdown. A relief valve may be provided, but unless it is occasionally moved it becomes set, and is not reliable. The success of this system, however, depends mainly on the design and sound construction of the pump and pump valves, but if sufficient attention be given to screening the sewage, and also the sludge before it enters the pump, the choking and slip of the valves, which usually occur, will be greatly reduced, and a steady pressure will be maintained.

The pumps employed are of various forms, but the one in most common use is that of the external packed plunger type, with steam for the motive power. The plunger type is preferable as being accessible, and it can be kept tight or the packing renewed, whereas with the internal packed type, the gritty substances rapidly cut the plunger and pump barrel, and excessive slip may be going on for a considerable time, as it cannot be readily detected until the pump fails to do its work, or is opened for inspection. When it is considered that the load on the pump is equal to a column of water 200 feet high, and that the plungers rarely exceed 4 inches diameter, the necessity for being absolutely tight is apparent.

The following is a description of the Drake and Muirhead forcing system as applied to several sewage works. It is given by the author as it presents several practical advantages of importance. The sludge from the precipitation tanks is received into a pit underneath the press house, from which it is pumped to a high level agitating vat, where a small proportion of ground lime is added. From there it is forced direct into the presses by a horizontal engine of the steam duplex type. This form of engine readily adapts itself to variations of pressure, and by the slide valve arrangement, one or other of the ports must always be open. There is, therefore, no dead point, and the engine continues to work until the pump pressure is equal to that of the steam cylinder. The steam cylinders are placed side by side, and the one piston acts to give steam to the other, causing a movement similar to a pair of engines coupled at right angles, but with a slight pause at each end of the stroke, which allows the valves to seat without shock. For each side two external packed plungers are provided, which work into each end of a pump cylinder having a central partition. The plungers are connected together, by external rods, in such a manner as to cause them to work together as one plunger, thus when one is filling the other is forcing, and the action is that of a double-acting pump, and gives a steady pressure. The suction supply being above the level of the pump, assists the pump cylinder in filling, so that the engine can work at a high speed when required for charging. The suction and delivery chambers are fitted with hinged flap valves, and an arrangement is also provided for forcing them into position in the event of any large substances lodging on the seats.

The air-pressing or pneumatic system consists of running the sludge into a vessel called a ram, which is of sufficient size to contain a charge, and is provided with a dip pipe reaching nearly to the bottom. When this vessel is charged and the necessary valves shut, compressed air at from 80 to 100 lb. pressure is applied to the top of the sludge, forcing it up the dip pipe into the filter. The air may be supplied either direct from the compressor, or through the medium of an accumulator, according to the requirements of the case. An air accumulator or receiver for storage is usually provided, and the advantages of this are many when a large quantity of sludge has to be dealt with. By this means a filter with 1½ yards of cell space can easily be filled and filtration commenced in about 30 seconds, with only a slight variation in pressure, the air compressor working at a uniform speed. As the pressing operation is nearing completion the surplus power from the compressor is being stored in the receiver, ready to be drawn upon again when required. Thus, in comparison with the direct forcing system, not only a saving of time in pressing, but also a saving in labour, is effected ; much less attention being required with an engine performing such work than is necessary with a hydraulic pump working with a varying load.

The addition of a small quantity of fresh lime to the sludge immediately before being forced into the press greatly facilitates the solidifying process. The time taken to produce a hard cake depends mainly on the quantity of lime used, but against this it must be borne in mind that the greater the quantity of lime used the smaller the manurial value of the cake produced. In the Native Guano Company's process, commonly called the ABC process of sewage treatment, filter presses and the pneumatic system are employed. The object being to produce the sludge at the highest value as a manure, the use of lime is entirely dispensed with. The cake produced contains about the usual percentage of moisture, but the time taken in pressing is approximately twenty-four hours, and a much larger filtering area has to be provided than is necessary where a small quantity of lime has been added.

The pressing plant erected at the works of the Richmond Main Sewerage Board in 1891 consists of a building with a sludge reservoir underneath, three filter presses, two pairs of forcing engines, two double-acting lift pumps, one single-acting air pump, two mixing tanks, two pneumatic lime mixers, and all the necessary pipes and trucks. The building is 104 feet by 21 feet, and the sludge reservoir 64 feet by 19 feet, and capable of storing 200 tons of wet sludge. It is provided with a skimmer having a perforated surface 2 feet by 1 foot 6 inches, and a pinion and rack for adjustment, and is connected to a 4-inch pipe, communicating with the untreated sewage chamber.

The filter presses are by S. H. Johnson & Co., and are erected on a platform made of H-iron girders, built in the wall at one end, and supported on cast-iron pedestals at the other, covered with rough surface floor plates, Each press has a capacity for producing 1 ton of pressed cake, the total cell space being 30 cubic feet. The plates are of cast iron, and form 30 cells, each cell or chamber allowing the formation of a cake 34 inches square and 1½ inch in thickness. The drainage surfaces of the diaphragms are pyramid pattern, that is, the grooves or channels intersect one another at right angles. At 8 inches radius from the centre are four projections, which, with their counterparts, form stays throughout the press, all the bearing parts being machine-faced true to each other. The filtering medium is of jute canvas, cut in lengths of 6½ feet, and having two holes punched. The canvas is hung over the plate, completely covering both surfaces, and the holes conform with the feed-passage through the plate, around which the cloth is securely fixed by means of a quickly closing brass union, which secures the cloth effectively by a quarter turn. The arrangement for opening and closing comprises a screw 4 inches diameter, and thread of buttress section 2½ to the inch, carried in a screw bush 8 inches long, and actuated by a double-purchase gear, consisting of a helical spur wheel 3 feet 3 inches diameter, geared to a 7¼-inch pinion, on a mandril, to which is attached a capstan wheel 4 feet 6 inches diameter, and is of sufficient length to allow of an opening of 1 foot 3 inches for removal of the cake.

The two pairs of forcing engines are each of the same dimensions, viz. two steam cylinders 6 inches diameter, with slide valves cutting off at 0·6 of the stroke, and pumps 4 inches diameter and 12 inches stroke, secured to cast-iron bases parallel to each other, and a fly wheel 4 feet 6 inches diameter, weighing 15 cwt. The pump plungers are connected direct on to the piston tail rods, and are single acting, working in stuffing boxes 6 inches deep, packed with hemp. The suction and delivery valves are circular in form, the guide being cast on the valve box cover, thus giving a clear opening. On the delivery main there is an air vessel or accumulator 4 feet 4 inches by 1 foot 4½ inches.

The two horizontal lift pumps are independent of each other, with steam cylinder 6 inches diameter, and pump 6 inches diameter by 12 inches stroke, secured to a cast-iron base plate, and acting without rotary motion. A link gear attached to the piston-rod gives motion to an auxiliary slide valve, which admits steam to the cylinder through the medium of a piston, to which the main valve is attached. The pump plunger, working in a cylinder, is double acting, and was originally fitted with spring rings, which have since been replaced with rope packing. This form of pump, although unsuitable for high pressure, answers sufficiently well at a low lift, as in the present case. The pump valves are of the same pattern as those on the force pump. One single acting air blower, having a steam cylinder 4 inches diameter and 8 inches stroke, and air cylinder 8 inches diameter and 8 inch stroke, working at low pressure, supplies compressed air for mixing purposes.

Two pneumatic lime mixers, shown at Fig. 5, are 2 feet 6 inches diameter and 2 feet 6 inches deep, and are worked in the following manner :—A charge of lime in lumps is placed on the grid inside the vessel and is sprinkled with sufficient water to slake it, and the cover of the vessel shut. After the lapse of a few minutes, the valve is opened and a further quantity of water run in until the lime is completely submerged. During the wetting process a jet of air from the air pump is admitted; it agitates the contents, and keeps the holes of the grid open. The milk of lime is then drawn off by a valve, the outlet passage being kept clear by the action of the air.

In 1894, additional pressing machinery was erected, consisting of three filter presses, a duplex air compressor, an air receiver, two sludge rams and all the necessary pipes for pressing by air pressure, and a system of pipes for ventilating the sludge reservoir and tanks. The three filter presses are of the same capacity as those put down in 1891, but they differ somewhat in point of detail. In those first put down the feed passages are 3 inches diameter, whereas those of the later presses are 4 inches diameter. This was arranged as a partial preventive to the blockage of the feed passages, and it has been found very valuable in that respect. The drainage surfaces of the plates are not pyramid pattern, but simply grooved vertically, and the bevel edge at the rim is carried inward 2½ inches, thus avoiding sharp angles, and consequently the excessive wear and tear of the cloths which took place in the presses first erected, the bevel being 1 in ¾. The projections or bosses on the surface of the plates are also made with an easy taper for the same purpose. The opening and closing gear is also of different design, and consists of a 4-inch screw working in a screw bush 8 inches long, the power for turning being obtained from a worm and worm wheel worked by hand from a capstan wheel 2 feet 6 inches diameter. Although this gear is not more powerful or quicker in its action than the other, it takes up less space, and was adopted so as to avoid altering the roof timbers of the building.

When the additional plant was erected, provision was made for removing the steam cylinders and pump end of one of the forcing engines, and providing two larger steam cylinders and two double-acting air-compressing cylinders, the other parts of the engine remaining the same. The steam cylinders are 8 inches diameter and 12 inches stroke, and the air cylinders 7 inches diameter and 12 inches stroke, jacketed with water in circulation. The pistons are of the buffer type, with springs so as to avoid clearance at each end of the stroke. The valve boxes are cast on the cylinder covers, and are provided with a quick opening and closing arrangement for access to the valves, which are of aluminium-bronze, and of sufficient area to allow of a low lift. The valve arrangement is shown in Fig. 6. Each end of each cylinder is separately connected to the delivery main, and is provided with stop valves, so that either end can be cut off, and the valve cleaned or replaced without stopping the engine. The cylinders can be worked single acting if desired, and by this means a high speed can be maintained, the whole arrangement being such as to give the highest efficiency. The air storage receiver is made of ½-inch mild steel plates riveted together. It is 4 feet 6 inches diameter, and 12 feet long internally, and is provided with a safety valve, pressure gauge, and a dip pipe for the removal of condensed water. The sludge rams are of cast iron, with hemispherical ends, and in three pieces with flanged joints bolted together. It is 5 feet diameter and 9 feet 6 inches long internally, and is provided with a 6-inch dip pipe, and all the necessary valves and connections. All the stop valves in connection with the sludge main are of the plunger type where they can be applied.

Before describing the method of working the foregoing plant, it may be desirable to mention that the sewage, before being treated, is passed through three screens, one of 1-inch and two of ½-inch mesh. The chemicals used for precipitation are lime and sulphate of alumina. The sewage is collected on the continuous flow system, the tanks being cleared about once in each week. For this purpose a floating arm and valve is provided, which will only permit of drawing the water down to within 4 inches or 6 inches of the top of the sludge, the whole of which is swept into the sludge reservoir together with the sludge, where the solids readily subside. The water is drawn off the top by means of the skimmer already described, and is conveyed back to the untreated sewage chamber and mixed with the crude sewage as it enters the works. The sludge is raised from the reservoir by the lift pumps into the mixing tanks. Originally the suction pipe of the lift pump was placed in the centre of the pit, but it was found that the supernatant water flowed to that point and filled up the cavity made by the removal of the sludge, and had to be pumped up and forced through the presses before a further supply of sludge could be obtained, causing a considerable delay in pressing, besides the extra wear and tear of the filter cloths. To obviate this, the suction pipe was extended to a point near the end of the pit, so that when the pump is at work the water flows to the suction pipe as before, and is readily taken off by the skimmer, which is situated near that point.

The following is the method of working the plant which is shown in Figs. 7, 8, and 9:—The sludge is raised from the reservoir to the mixing tanks by the lift pumps. A proportion of lime varying from 3½ to 5 per cent. to the ton of pressed cake is slaked in the lime mixer and run into the mixing tanks.

A jet of air from the single-acting air pump is admitted at the bottom of the tank, and the action of the air passing upwards thoroughly mixes the lime and sludge together. If it is desired to utilise the force-pump system a valve is opened, and the limed sludge is conveyed through a 4-inch pipe to the force pump, by which it is forced direct into the presses. When it is desired to utilise the air-pressure system, the sludge is raised to the mixing tanks and limed in the same manner as for the other system, and conveyed through a 6-inch pipe to either of the rams. When the ram is charged and the necessary valves adjusted, compressed air from the storage vessel is admitted to the top, and the mass is forced up the dip pipe into the filter press. Each ram when full contains a sufficient quantity of wet sludge to charge one press. While one is under pressure the other is charged and got ready to follow on. When another press is ready for charging, the air communication between the storage vessel and the rams is cut off, and the air in the ram under pressure is admitted through a bye-pass to the ram containing the fresh charge. The empty press is then opened and filled with sludge forced up by the pressure of the waste air from the first ram. Thus a considerable saving of compressed air is effected, as the whole of the air must be allowed to escape before the ram can be again charged with sludge. The filtrate from the presses is collected in troughs and conveyed back to the untreated sewage chamber, and the pressed cake from the presses is dropped into tip wagons on rails underneath. Each wagon is made to contain one ton of cake. The air-pressing system is usually employed, the force pump being retained as a stand-by or reserve.

Before the air-pressing system was adopted the breaking of a plate was of frequent occurrence, and maintenance became a somewhat heavy item. Although the sludge was screened before being forced into the press, the feed passages occasionally became choked, and if at the same time one of the pump suction valves was hung up, the whole of the power from the two steam cylinders would be transmitted to the one plunger, and an unsteady rise in pressure occurred, resulting in the breaking of the plate. Since the adoption of the air-pressure system no fracture has occurred. When the force pump is employed, one of the air-forcing rams is usually employed as a cushion vessel.

Experiments having been made with different qualities of filter cloth, it was found that the cheaper and thinner sorts answered as well as the better class, so far as filtering was concerned, but were worn out much quicker. Tanned canvas and copperised canvas was also tried. These lasted slightly longer than untreated cloth of the same quality, but not sufficiently long to compensate for the extra cost. As a result of these experiments a stout jute canvas is now employed. This material wears until the fibres become so matted together as to prevent the escape of the filtrate. Cocoa matting has also been tried, but the plates are unsuited for that material.

Experiments have also been made with different kinds of lime for pressing. Greystone lime was found to be the best for the purpose, and is now used in lump form, the pneumatic lime mixers rendering the use of ground lime, with its extra cost for grinding, unnecessary.

Trials of the air-pressing and the direct-forcing system have recently been made, and the results are given in the following table:—

	—	By Air Compressor. Six Presses. Jan. 26, 1897.				By Force Pump. Three Presses. Jan. 29, 1897.			
		tons	cwt.	qrs.	lbs.	tons	cwt.	qrs.	lbs.
1.	Weight of wet sludge	133	7	2	11	76	9	1	1
2.	Pressed cake	29	3	3	4	15	5	3	6
3.	Water expressed	104	3	3	7	61	3	1	23
4.	Total revolutions .. .. No.	44,574				27,484			
5.	Average revolutions per minute ..	72·47				43·97			
6.	Average mean pressure	26·512				17·292			
7.	Average pressure in presses lbs. per sq. inch	76·3				57·66			
8.	Indicated horse-power of steam cylinders	11·70				2·60			
9.	Time in hours .. .. (Labour same in both cases.)	10				10			

It will be observed that the trial of the air-pressing system was made with six presses in operation, and the direct forcing system with three presses, so that for a comparison of the two results the figures of the direct forcing system must be doubled.

The resident population of the district draining to these works is 50,000 (in the summer months this is much increased), and the average quantity of sewage is from 40 to 45 gallons per head per diem, or a total of from 14 to 16 million gallons per week, exclusive of storm water. From this the wet sludge obtained is opproximately 625 tons, which is reduced to from 110 to 120 tons of pressed cake, according to the time of year. To accomplish this, the pressing plant is in operation five days of ten hours each per week.

The approximate cost at present per ton of pressed cake is as follows:—

	s.	d.
Labour	0	10
Lime	0	9
Cloths	0	4
Coal, oil, &c.	0	3
	2	2

DISCUSSION.

The PRESIDENT said he felt sure that they would all join with him in according a hearty vote of thanks to Mr. Croll for his paper. It was a very able descriptive paper, especially with regard to the process of sludge pressing as it was carried out at Richmond. There were many other towns in this country which were situated in the same way as Richmond. They had large populations, and their sewage must be treated by chemical precipitation, and they were without land available for the treatment of the effluent. Of course, in those cases in which precipitation was used sludge was produced, and with one or two notable exceptions the only way of getting rid of it was by means of filter presses. There were few towns, if any, where sludge could be barged out to sea in the way it was at the London outfalls.

The vote of thanks was passed by acclamation.

Mr. W. SCHÖNHEYDER said that the author had described two principal methods of forcing sludge through the press. One was the direct system which was carried out by means of ordinary pumping, and was, no doubt, the most economical of the two, as shown clearly by the experiments recorded at the end of the paper. From an economical point of view the advantage of pumping was as two to one. But certain difficulties interfered with the pumping, such as the presence of solid materials. The other method of forcing the sludge through the press was that of air pressure, and since the introduction of the air-pressing system the disadvantage of breaking the plates had been avoided. He could not see any reason why the plates should be broken in connection with the direct pumping system. The pressure upon the plate would be about 80 or 90 lbs. to the square inch, and there was no difficulty in making the plates strong enough to resist that. A relief valve on the pump would naturally be provided. If that were made, as it should be, of sufficiently large size, it would prevent any accumulation of pressure, and therefore it ought to be quite impossible that the breakage of a plate should take place in a properly designed system. If the relief valve were made so that it would stick fast occasionally, the pump might bring an excessive pressure on the whole system and do some damage, but there was no difficulty in providing a relief valve that would not stick fast. Works all over the world depended upon relief valves, and there would be no more difficulty in providing an efficient one for a sludge press than for any other purpose. The same difficulty did not take place when air compression was used. That was because it was impossible for the air to come to more than a fixed pressure, and therefore it would do no damage; but that was necessarily an expensive system, as anyone would know beforehand.

It seemed to him that a very much better way of forcing the sludge in would be to apply hydraulic pressure. He would use a vessel something like that shown in Fig. 5, with a hydraulic leather collar and plunger from the top worked by hydraulic pressure. If the sludge was filled into the opening while the plunger was above it, and then when sufficient had been allowed to run in, the plunger was to descend into the cover and force down the sludge, they could then do away with valves entirely, and they would have a very steady pressure from the hydraulic cylinder which could not possibly exceed a certain amount, and would therefore do no damage. He thought that the same means should be employed in pulling back the plates in the presses and also in forcing them together. That would save a certain amount of time and the work would be done more quickly. That in the long run would be quite as cheap as ordinary pumping. He would ask how the plates were perforated. Had they a number of holes, and if so, what was the size of the holes, and what was their distance apart? He had failed to see any explanation of these points in the paper.

Mr. G. CHATTERTON said he doubted whether Mr. Schönheyder was correct in saying that there was a very great economy shown in the table, with regard to direct pressure over compressed air. Further on the author gave the cost of labour, lime, cloths, coal and oil; the cost of coal and oil being 3*d.* out of the 2*s.* 2*d.* It seemed to him that that was the only item in which economy would occur, and it amounted only to 3*d.* out of 2*s.* 2*d.*, which was not very much. It had always struck him that direct acting pressure would naturally be the best way of dealing with the present question. Some ten years ago he specified in a certain work that direct pressure should be used, and a well-known firm of sludge press makers decided to carry it out; but after a while, and before the work was actually erected, they came to him and asked him to allow them to substitute compressed air for the direct-acting pump. They said exactly what the author had stated in the paper. The direct-acting pressure was unsatisfactory on account of the breaking of the plates. He, of course, was very glad to relieve them, and the compressed air system was installed instead, and it had never occasioned any trouble. For one direct-pressure system he heard of fifty or a hundred cases in which compressed air was used.

With regard to the subject generally he would say that no one except those who were intimately connected with such works knew the value of sludge presses. He would go further than the President had when he stated that in certain places where they had not sufficient land to deal with wet sludge they were bound to come to sludge presses. The President seemed to imply that there might be certain places where they could deal with wet sludge on land. After a considerable amount of experience with regard to the matter he (Mr. Chatterton) had formed a very strong opinion that there were very few places indeed—except where there were enormous areas of land compared with the quantity of sewage—at which they could deal with wet sludge on the land. No matter how carefully wet sludge was applied to land it became an abominable nuisance and great care had to be taken with it. There were many sewage works in the neighbourhood of London and in the suburbs of towns all over England where residences had sprung up close to sewage works which had a considerable area of land; but if the works were to revert to the old process of dealing with the wet sludge on the land they would certainly have actions brought against them in a very short time. The sewage press had become an appliance of great value, and therefore a paper like the present was important as giving details of the system, and an account of the latest improvements that had been made. The table given was of very great value. The only fault that he found with it was that it was limited to the experience of one day. He would like to see a table giving the result of a week and a few more details, including the analysis of the sludge before it was pressed.

There were very few places which had the advantage possessed by London of taking the sewage out to sea. He was carrying out works at a place from which they would be able to carry the sewage out into deep water by taking it only seven miles, and dispose of it without causing injury or damage. Sewage presses could not compete with an advantage of that kind. Statements had been circulated to the effect that certain processes of dealing with sewage sludge in the future would require no sludge presses whatever, to say nothing of using no chemicals, for the simple reason that there would be no sludge. If a time arrived when that came to pass it would be a very bad day for the makers of sludge presses, but he would advise them not to give up making sludge presses at present.

One of the first systems of sludge pressing machinery which had been put up in this country was put up at the Merton sewage works about seventeen years ago, and it had been at work ever since. He was now removing it, but it had certainly done a great deal of very good work. The district had grown enormously since the machinery had been there, and the presses were now thoroughly antiquated. It was very interesting to compare them with the sludge presses which were being put up at the present time.

Mr. J. C. Melliss said that the paper was a valuable practical addition to the literature of sewage. The author had had an opportunity of practically testing what he had described, and he did not speak of theories at all. He (Mr. Melliss) had himself been practically engaged in the matter, having been the engineer for the first sludge pressing plant that was put up in this country, and that was erected nearly twenty years ago. The outcome of it had been very great, and sludge pressing plant was now very largely employed throughout the country. In his opinion no sewage precipitation works were complete without sludge presses; and, like Mr. Chatterton, he fully believed that sludge presses would continue to be required. One interesting point in the paper was that at Richmond they had had the opportunity of testing the direct forcing of sludge into the presses, and also the forcing of it in by means of compressed air, and the plant for the two processes had been put up side by side. Such a condition of things did not occur in any other works that he knew of, and it was very interesting to see the result of the two methods. He knew that Mr. Croll expressed himself in favour of the compressed air, but a few more particulars about the cost of the two methods were required. If Mr. Croll would give them they would be a valuable addition to the paper. The life of the cloths was also an important point. The cost of pressing was largely increased by the number of cloths that were required, and some further particulars upon that point would be very interesting.

Mr. W. Fairley said he quite agreed with Mr. Chatterton and Mr. Melliss, that although they heard at the present time of works where no chemicals and no machinery of any kind were used, still sludge pressing in connection with chemical precipitation had a great many years to run before it would quite go to the wall. Mr. Schönheyder had spoken about the advantages which he thought would be derived from the use of hydraulic pressure, and he understood him to mean that in Fig. 5 he would have a ram or a receiver with a plunger or a piston actuated by hydraulic pressure. But he (Mr. Fairley) considered that the pneumatic system had advantages over such a system, because in the pneumatic system they had the power put into the ram as compressed air and at the same time forming a plunger or piston moving without any friction. Anyone who had practical knowledge of sludge and the pumping of it would be acquainted with the practical difficulties in direct pumping. The same speaker seemed to think that there would be no difficulty in getting a plate strong enough to stand 100 lb. pressure. He (Mr. Fairley) could assure him that manufacturers found difficulty. It must be remembered that the plate was made of cast iron. It was not perforated, as Mr. Schönheyder seemed to think. The water went through the cloth and along the face of the plate. The plate was not a grid, and the whole force was on one side of it if the central passage was blocked. It would be noticed that in one of the plates shown in the diagram there was a sort of belly on the plate. A buckled plate was supposed to have an advantage in respect to strength. He could not speak upon that point himself, having had no experience of buckled plates. The renewing of plates was a very serious item of expense. The relative advantages and disadvantages of the two processes, the direct pumping and the pneumatic process, could not have justice done to them in a table. The reason was that there was theoretically no question that the direct pumping was more economical, but when they came to practical working and the time lost, possibly, in clearing the pump valves, in renewals and so on, direct pumping was not more economical than the pneumatic system. Again, by means of a properly designed system on the pneumatic method the cost of labour could be very much reduced.

In Figs. 7 and 8 all the machinery was shown in the building with the presses. Personally he should prefer to have the steam engines and machinery kept out of the press house. They should never be there at all. There was no difficulty in allowing the engine driver in the main engine or pump room to attend to the compressors or pumps. By that means they would save an item of considerable expense in the special example, namely, the skilled labour. He held that when they compared the relative advantages of the direct pumping and the pneumatic processes they must look at the cost. Coal and oil were found to be a very small item, and labour, a large item, could be reduced by means of the pneumatic system. It had been said that a hydraulic cylinder would be handier for opening and closing the movable head of the presses, but he had been assured by those who had practical knowledge of the subject that there was no saving of labour by putting in air or hydraulic cylinders as against ordinary gearing. There was no difference in time. The whole thing could be done quite as quickly and economically with the ordinary capstan wheel.

Mr. Perry F. Nursey said, as he understood it, the filter plates were made with a single central circular opening.

Mr. Fairley said that he had mentioned that the plate was a solid plate. It was not a grid. It had a central opening. But the central opening sometimes got blocked up, and then the pressure was on one side. The central opening went right through the system of plates in each press.

Mr. Nursey asked the author whether he had ever known of the application of horsehair cloth in filter presses. He saw it used in a filter press for a special purpose some years since, and he was under the impression that it had been tried for sludge filter presses.

Mr. R. E. Middleton said he thought it would be useful if the author would amplify the table by making an absolute balance sheet of cost. The question of repairs was left out, and therefore there was no record of the cost of the renewal of the plates which were broken when compared with the extra cost of horse-power. The cost of the coal and iron and so on was also omitted. He would ask the author why there was the enormous loss of efficiency in the air-pressure process as compared with direct pumping. The efficiency as regarded horse-power and water expressed was three to one in the direct system as compared with the other as shown by the table. He did not know why the pneumatic arrangement should be so exceedingly inefficient. He thought there must be something wrong in the particular case referred to. Probably on a more extended trial there would be found to be greater equality between the two processes as regarded efficiency.

Mr. W. Dawson said, with regard to the breaking of the plates, he thought if there was a 4-inch feed passage, and the sludge was screened, there would be no difficulty. At Leyton there was only a 3-inch feed passage, and the insertion of the clips reduced that size to 2¾ inches. Analyses of Leyton sludge had been made by eminent chemists, and tests had been made by experimental agriculturists, showing that the sludge was really a valuable manure, and he had been led to expect, when the presses were started, that about 1*l.* per ton could be made of it. He believed that the real value was put at 18*s.* 6*d.* by Dr. Munro. He (the speaker) had been pressing sludge for the last fifteen years, and had increased the number of his presses from two to six, and had been turning out some thousands of tons of pressed sludge every year, but he had never been able to sell a ton. He had put it on trucks free and sent it down to the Essex farmers, but the order had never been repeated. He had found a difficulty in knowing what to do with the material, and the cost of its removal had increased every year. In 1895 and 1896 the removal cost something like 300*l.* a year. After many trials of disposal, he advised his council to adopt the destructor method.

After seeing nearly every type of destructor in England, the Council adopted the Beaman and Deas destructor, which had now been at work for over twelve months, consuming all the house refuse and sludge in something like the proportion of two of the former to one of the latter, and they were turning out a very good clinker and ash, which was all readily disposed of. The sludge was burned immediately it came from the presses. They had two 100 horse-power boilers, and they drove a dynamo and all the pumps, and the pressing and mixing machinery at the sewage works, and saved a coal bill of something like 350*l.* a year; and thus they had solved the problem of disposing of the sludge. There was now an accumulation of something like 4000 tons of sludge deposited on land at the sewage works waiting to be burned. It had accumulated before the destructor was at work, and when the deposit of sludge cake had been stopped on the land. He thought it was well that such facts should be known to people who thought of getting sludge presses, and entertained the idea that the sludge could be disposed of. He did not know of any place where it had proved of any value at all, and Leyton was the first place in England that burned pressed sewage sludge.

Mr. A. Hanssen said he was one of those who were inclined to believe that sludge pressing would soon be done away with. He was connected, through Messrs. Shone and Ault, with the works at Hampton, where the Urban District Council had called in Mr. Dibden to advise them about sewage filters. He had seen sewage filters at work at Sutton, where they had been working, as he was informed, for a year, and had given a thoroughly satisfactory result. There was no sludge whatever, and the effluent was clear, and there was no smell in the filtering material. He therefore thought that there was a fair chance of getting over the sludge difficulty. With regard to the hydraulic system of sludge-pressing plant, he could only say that it did not seem to have been very satisfactory. He remembered a plant at Esher, which he had an opportunity of seeing at work. The hydraulic sludge pumps had only been at work about four or five years, and the 4-inch plungers had been worn down to nearly 3½ inches in that time. In places they were deeply scored, so that it was almost impossible to keep them tight. He thought that was the best proof that could possibly be adduced against the hydraulic pumping of sewage sludge.

Engineers who had not had actual experience with sludge and sewage had no idea what difficulties were connected with those materials. It had been proposed, for instance, to pump sewage at various points in urban areas by means of hydraulic pumps, but that was nearly always a failure. As long as the sewage was highly diluted and consisted practically of clean water, the pumps would work; but as soon as thick sewage was dealt with the pumps became clogged, they got scored, the friction of the plungers increased, and the difficulties of pumping became exceedingly great. He had had to design sludge-pressing plant for Walthamstow, in which, instead of having big rams, which were generally employed, they used small-sized Shone's sewage ejectors. The ram contained over 1000 gallons of sludge, but the small ejectors contained only about 50 gallons, and worked automatically and filled the presses gradually. Many people had great misgivings with regard to them at first, and thought it impossible to fill a press by such small charges. He, however, had not found it so. With a little care and attention the work could be done very well, the cost of the plant was reduced, the work was very much simplified and made automatic, which was not the case with a big ram. He wished to call attention to one point, though it was a very small one. It was that an air compressor should always be spoken of by that term, instead of being sometimes called an air pump and sometimes a blower. The use of the term "air pump" suggested an apparatus for producing a vacuum, as it had been used for describing a vacuum pump since the time of James Watt, and it was confusing to use it for an air compressor.

Mr. J. C. Fell, referring to the point raised by Mr. Middleton as to the obvious loss in economy in the employment of pneumatic pressure as compared with the direct forcing, said he had seen a great deal of the employment of compressed air for the purpose of working underground machinery, and in all cases the loss, as between the actual mechanical effect produced by the compressed air and the original force employed to compress the air, was very great. It was generally said that if they got 33 per cent. of efficiency they were doing very well in ordinary compressed air plants; so it would seem, without any doubt, that if it was desired to employ compressed air as an intermediate means of forcing the sewage into the presses, it must be paid for, at any rate, in the loss of efficiency, as compared with the efficiency of the fuel employed in the furnaces of the boilers. He had no doubt that the question of repairs and the uniformity of pressure which could be so readily controlled in the case of compressed air, would put the balance on the other side if the author were to give the complete balance of the two processes compared one with the other.

Mr. Dawson asked whether the author could state what was the reason that the ABC Company or Native Guano Company took twenty-four hours to compress, when the usual time was only one hour. He should also like to ask the author as to another point. He understood that when Drake and Muirhead's presses were first put on the market no cloth was used in the filters, but that cocoa-nut matting was used. That must have been a great saving, as the matting, he was told, lasted nearly a year, and press cloth lasted only about a month.

Mr. Schönheyder said that Mr. Dawson had referred to the burning of sludge cake with house refuse. Were they to understand that the sludge cake possessed a calorific value, or did the house refuse burn the sludge; and was the burning of the sludge simply a means of getting rid of it?

Mr. Dawson said the sludge had no calorific value at all. It was simply burnt by means of the house refuse.

The following communication from Mr. T. W. Baker, dated October 2, 1897, was read:—

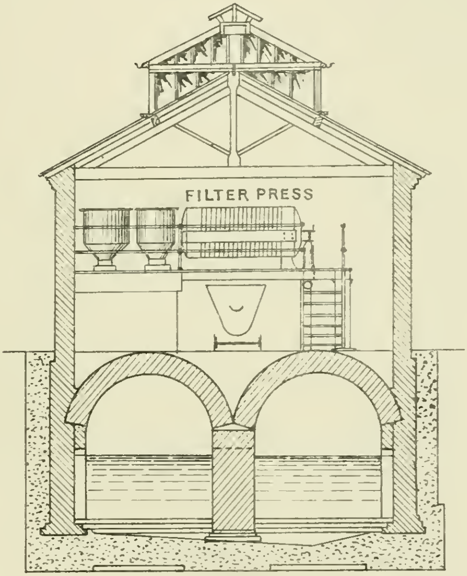
In the useful information imparted in his paper the author has admitted the faults of the present system in the following sentence: "It must be borne in mind that the greater the quantity of lime used, the smaller the manurial value of the cake produced." In Glasgow it has been found that sewage sludge or cake has a value of about 25*s.* per ton, while at Leyton and other sewage works near London, great difficulty arises in its disposal, and burning is resorted to, the admixture of lime being a great factor in the low manurial value.

The experience I have recently gained at Henley with the use of the Reeves system shows a very high manurial value has been the result, and to use filter presses to convert this sludge into a marketable manure some better arrangement needs to be introduced to obviate the use of lime as a coagulum, at the same time to obtain an equal output from the presses. But it may occur that evaporative methods would have better results as being less likely to disturb the nitrogenous products, and throw them into the filtrate liquor.

Major Lamarock Flower, at the Leeds Sanitary Congress, recently pointed out that the waste of the sewage manurial products should be diverted to the resuscitation of the land in lieu of polluting rivers, and that it can be accomplished is clearly demonstrated at Henley. If filter presses can be better adapted to prevent the necessity of bringing down (by the admixture of lime) the amount of moisture from 90 per cent. to 60 per cent. the destruction of valuable manurial products may be prevented.

Mr. Croll said he could not give Mr. Melliss the information that he asked for offhand, but he would be very glad to send it to him. Mr. Nursey had asked for some information with regard to the use of horsehair cloth. He could not give particulars of that material. He believed cocoa matting lasted longer than anything else for sludge pressing. It had been known to last for fourteen or fifteen months. Another speaker had made some remarks about the low efficiency of the air compressor. The only explanation which he (the author) could give of it was that, each time a ram was emptied of sludge, the air from the empty ram was used back on the full ram, expanding until down to about 40 lb. pressure, and that had to be allowed to escape before the empty ram could be charged again. He should say that was where the loss on the air-pressing system took place. Again, with the forcing system there was a very great loss due to the gritty matter on the valves. That lodged on the seats of valves, allowing slip, in some cases to the extent of 75 per cent., and the engines would run fifty or sixty revolutions without pumping at all.

Some remarks were made with reference to the air compressor being called an air pump. He thought that if the paper was looked through again it would be noticed that the air compressor was generally spoken of as an air compressor, and that the air pump which was mentioned was the one used in connection with the mixing of sludge and lime together. In that case the air was simply forced through to agitate the lime and sludge together. With regard to the time taken in pressing with the ABC process, they produced a cake similar, as regarded percentage of moisture, to the cake which was produced with the addition of lime, but the presses were kept under pressure for about twenty-four hours as stated in the paper. The sludge did not cake unless it was kept on for a very long time. In fact, when the presses were charged, a small quantity of water flowed at first, then dripped until the accumulation formed itself into a solid cake, without the assistance of the lime.



CROSS SECTION.

Fig. 9.

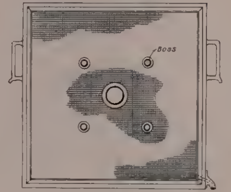


Fig. 1.

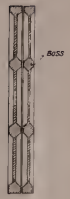


Fig. 2.

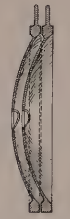


Fig. 3.

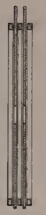


Fig. 4.

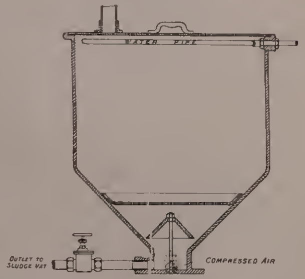


Fig. 5.

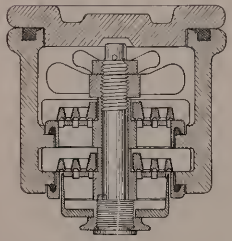
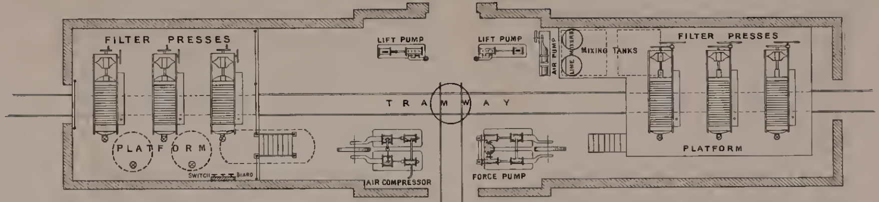
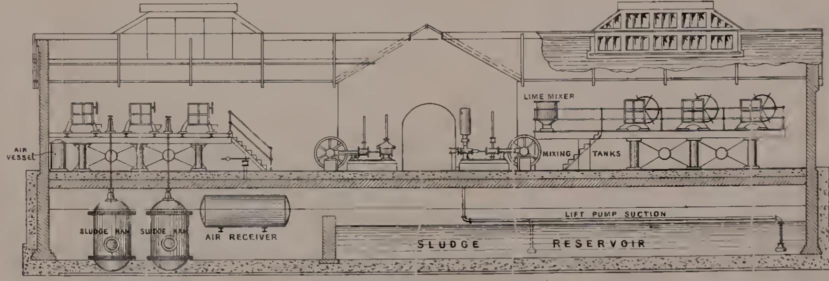


Fig. 6.



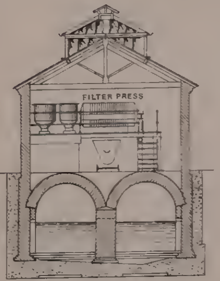
PLAN. (Fig. 7.)



LONGITUDINAL SECTION. (Fig. 8.)

SCALE

FEET 10 5 0 10 20 FEET



CROSS SECTION.

Fig. 9.

E & F N Spon Ltd. London

November 1*st*, 1897.

GEORGE MAXWELL LAWFORD, PRESIDENT,
IN THE CHAIR.

SEA DEFENCES.*

BY RICHARD FUGE GRANTHAM.

IN view of the rapid extension of seaside watering places, and the large sums of money spent on their protection from the sea, as well as of the importance, to owners of land and houses by the sea, of the protection of their property, the principles upon which such works should be constructed appear to the author to be worthy of the fullest consideration of engineers, and particularly when one remembers the diversity of opinion as to the forms which they should take. That the conditions of any one part of the coast differ from those of any other is not a sufficient explanation of the variety of forms of defence which are to be found along the sea frontage.

More than fifty years ago, at the reading of papers before the Institution of Civil Engineers upon the question of the best form of sea walls, opinion was divided on the respective merits of upright walls, and of long stone-pitched slopes following the natural inclination of the shore. The late Mr. John Scott Russell expressed the opinion that, for the purpose of reflecting waves, and not breaking them,† "with the best materials, best foundation, the most perfect workmanship, and constant care, there is no doubt that the shape in which the smallest quantity of material will most completely resist the action of the sea is the vertical wall," and he goes on to explain that an angle of 45° for the outer slope of the wall would bring it within the scope of his definition of a vertical wall, and would give "the advantage that it combines in the highest degree the action of weight of each of the stones with their pressure on each other."

The form of wall more recently constructed at various points on the coast coincides with this view, although perhaps its suitability as a support to an esplanade may have, to some extent, determined it.

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* The President's Gold Medal was awarded to the author for this paper.

† Min. Proc. Inst. C.E., vol. vi.

The rate of loss ascertained by the author at various points on the coast is as follows:—

	Feet per annum.
Between Westgate and Margate, chalk cliffs, 30 to 40 feet high above sea level	2
St. Margaret's Bay, near Dover, loam and gravel, about 5 to 6 feet above sea level	4 ft. 6 in.
New Romney Level, sandhills varying in height	8
Lancing Village, Sussex, ridge of shingle protecting low-lying land swept back by the sea. Average about	18
Elmer, Middleton, Sussex, part ridge of shingle, part loamy clay cliff, about 6 feet above sea level	3
Bracklesham to East Wittering, west of Selsea Bill, loamy clay with some gravel	5 to 8
East Wittering to mouth of Chichester Harbour, loamy clay and gravel, from 10 to 20 feet above sea level	10 to 15
Highcliff, east of Christchurch, Hants, slipping cliff about 100 feet above sea level. Sharp gravel and sand, 13 to 18 feet thick, overlying Barton clay	3

Mr. Robert Pickwell[1] stated that the average rate of loss of land between Flamborough Head and Spurn Point must considerably exceed 2½ yards per annum.

Other observers have found the rate of erosion to be:—

	Feet per annum.
[2] Easton Bavent Cliff, north of Southwold, light coloured sands, laminated clay, and shelly sands 11 feet high	21 to 30
[3] Between Eastbourne and Langley Point, rubble clay gravel	3
[4] Between Hengistbury Head and Boscombe Chine, east of Bournemouth, light coloured sands and dark clay, from 30 to 77 feet high	10
[5] Yaverland and Redcliff, Isle of Wight, about	3
[6] Lyme Regis, Lower, lias clay on limestone	3
[7] Bridport Harbour, East Cliff, sands and calcareous sandstone	1
[8] Bridport, West Cliff, clays and marls	1 to 3
[9] Westward Ho, for about a mile in length, about	30
[10] Watchet, cliff, about 56 feet high, red and grey marls (Rhætic)	4

This loss produces littoral drift, the subject of a recent paper[11] by Mr. W. H. Wheeler, M. Inst. C.E. The author, however, from his experience, shares the opinion expressed by other engineers that the movement of this drift is due to the waves created by the prevailing wind of the locality, and not to the wave action of the flood tide, although in most cases its direction coincides with that of the flood tide.

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[1] Min. Proc. Inst. C.E., vol. li.

[2] Proc. Geol. Soc., vol. iii. p. 445.

[3] J. B. Redman, Report to War Office, 1857.

[4] Quart. Journ. Geol. Soc., vol. xxxv.

[5] Report British Assoc. Committee Erosion of Coasts, 1886.

[6] Ibid.

[7] Ibid.

[8] Ibid.

[9] Quart. Journ. Geol. Soc., vol. xl.

[10] Ibid., vol. xxiv.

[11] Min. Proc. Inst. C.E., vol. cxxv.

Now the sand and shingle thus transported are the most important elements in the protection of the coast. In ordinary times they in some degree prevent the constant fretting away of the foot of the exposed cliffs, or, when piled up in a ridge on low-lying land, check the advance of the sea. Clearly, then, the removal of this sand and shingle in large quantities weakens the natural defence of the coast line, and ought in all cases to be stopped. Thus, the author found that west of Selsea Bill shingle was being taken for repairing the parish roads, and that barges were removing 100 tons of shingle per week from the Spit at the mouth of Chichester Harbour. By the advice of the author, the Lords of the Manor prohibited the practice. A similar custom prevailed on the Yorkshire coast, and the trade in shingle was largely developed by the opening of the Hull and Holderness Railway. The Board of Trade put a stop to it, the late Sir John Coode's evidence being that "if the shingle continued to be removed, the port of Hull would be endangered, and that materially so." *

The artificial defences against the sea are:—

I. The embankments which protect the low-lying and reclaimed lands, generally of earth with pitched slopes.

II. Upright stone or concrete walls, some of which have groynes in front of them.

III. Groynes of timber, stone, or concrete.

I. *Embankments.*—The most familiar forms of these (see Fig. 1) have, where exposed, a front slope of 4 and 5 to 1, a back slope of 1½ and 2 to 1, and a height of from 6 to 16 feet above high water spring tides. The front slopes are sometimes pitched with chalk or stone, or, as in Holland, are protected by fagoting. The walls of Canvey Island in the estuary of the Thames, four miles west of Southend, have for some years been under the charge of the author, and are typical of this kind of defence. In 1881, the sea broke into the island—its surface being about 3 and 4 feet below H.W.O.S.T.—and flooded about 1500 acres. The top level of the walls, which are 16 miles in length, at that time was about 15 feet above Ordnance Datum, and the width 3 feet. The outer slope of the wall, which is 4 miles long, fronting the Thames, is faced with Kentish ragstone pitching, about 40 feet wide in the most exposed parts (Fig. 2). The author first raised the front walls to a height of 18 feet above O.D., and the back walls to 16 feet O.D., the highest known tide being 15 feet O.D. The stone pitching of the front walls was broken up, and spread as a layer 12 inches thick, and upon this dry stone pitching, averaging 15 inches thick, was laid.

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* Min. Proc. Inst. C.E., vol. li.

It is not known when the island was reclaimed, but the history of the maintenance of the walls commences about the year 1620 A.D. It is not likely that the stone pitching of the front slope was undertaken all at once. The probability is that the front wall was first formed, as is usually the case, a little distance from the margin of the saltings, the edge of which is generally broken and fretted away by the action of the waves, a mud-covered slope being left in front. As this broken edge approached the foot of the front slope it was probably sloped back and pitched with stone with a row of oak stakes driven in at the foot. Waves rolling up and down this slope would immediately begin to scour off the mud at the foot and undermine it; the pitching would then be added downwards with another row of oak stakes at the foot. This process would be continued until the foot of the slope had reached its present level of about 8 feet below H.W.O.S.T., or 8 feet above L.W.S.T. The slopes now have inclinations of from 3¾ to 1 to 4½ to 1. But in order to prevent further scour, low stone-pitched groynes were run out at right angles to the front line, and these groynes at the present time cause some small accumulation of drift sufficient to prevent further undermining.

The well-known Dymchurch wall (Fig. 9), from its exposed situation, is an exception in its form to the class of sea defences now under consideration. It was formed at a time when the discussion already referred to on long slopes and upright walls was proceeding. The inclination of the sea slope was 6 to 1, 7 to 1 and 8 to 1, terminating at the upper end with a curve of 7 feet radius in an upright wall, the top of which is about 10 feet above the H.W.O.S.T. The breadth of the stone pitching when first laid was about 130 feet, the lower end being about 7 feet above L.W.S.T., or 14 feet below H.W.O.S.T. Further reference to the present state of the wall will be made under the head of groynes.

There are, so far as the author is aware, few earth embankments of reclamation areas faced with upright sea walls of any great length. Recently, however, he had to inspect and report upon the defences of the Caldicot Level, which is under the jurisdiction of the Monmouthshire Commissioners of Sewers, at the mouth of the Severn. The defences fronting the river, which is there about 5 miles wide, consist of the usual earth embankment faced for a continuous length of 6 miles with stone walls more or less upright. Owing to the circumstances in which they have been built, these walls present almost every variety of profile, from a slope of 2 to 1 to the perpendicular and curved. The section varies every 200 yards, and sometimes less; some walls are from 2 to 3 feet higher than those adjoining them, the general height being from 12 to 14 feet above the shore level. The rise of spring tides is 38 feet, and high water mark is within about 3 feet of the top of the lower walls. In storms, however, the surge of the waves frequently overflows. The base of the wall is bedded on the rock of the foreshore, but although it resists scour to some extent, it has been found necessary to form a broad apron of dry pitched stone in front of the foot of the wall to prevent undermining. The walls were much damaged by the storm of October 1896, and again in March 1897.

II. *Upright Walls.*—The prevailing practice at watering places in recent years, where a coast is exposed directly to the sea, has been, as already observed, to build walls more or less upright. But there is no uniformity in the profile of the face. At one place it is nearly perpendicular, at another it has a batter of one or two inches to the foot or more; sometimes it is curved more or less; and occasionally it is built up in steps. But while the form may be such as to aggravate mischief at the foundation, damage to, or the destruction of a sea wall is not generally directly due to its form or to the want of thickness or inherent strength of the wall, but to undermining.

As soon as a wall is built on a coast exposed to heavy seas, the sea at once begins to scour out first the drift lying upon the shore, and then the material of which the shore consists. With a perpendicular or slightly inclined face, the waves during the storm, suddenly checked in their advance, shoot up it or over the top volumes of water which, falling back, draw with them as they recede the sand and shingle at its foot, which are then by the following waves carried away to leeward. On a more inclined slope of 1 to 1 or 2 to 1 (see Fig. 3) the waves running up and receding scour away the materials at the top of the slope. Where there is a sharply curved face, especially when a nosing is added or the coping projects, the wave rises up and is thrown violently back on the shore at the foot of the wall. The result in each case is a general lowering of the level of the shore, so that deeper water is brought up to the wall. Unless it is founded on hard rock, or protected by groynes, its foundations will be undermined, and its destruction is only a question of time.

The author's firm built a sea wall at Westgate, Kent (see Fig. 4), where the shore and cliffs are of chalk. The chalk on the shore appeared hard, and was covered with sea-weed. The base of the wall was built 2 feet deep below the shore level. But in two or three years it was found that for some yards in length the foot of the wall had been undermined, and the chalk scoured out about 9 inches. The remaining lengths of the foundations were built 4 feet below the shore level.

Mr. Ellice-Clark * mentions the case of a wall he built at Ramsgate, where the curve of the face was made too sharp, with the result that the chalk foreshore was speedily undermined. At Blackpool † the cliff on the frontage was sloped down to an angle of about 50° and paved with stone. Scour caused by the run of the waves up and down the slope immediately commenced, and the stonework was undermined. The foundation was carried lower down, thereby increasing the scour, and the stonework had to be carried still lower down. The result was a permanent lowering of the shore and an increased depth of water, giving greater power to the waves.

At Brighton and at Hastings, in order to protect the front walls, the corporation have found it necessary to build large and costly concrete groynes. At Hove, too, the fine esplanade wall (see Fig. 5), built by the late Sir John Coode and Mr. Ellice-Clark, is protected by short timber groynes, without which the wall probably would not now be standing. But from the scarcity of the supply of shingle travelling along the frontage—the bulk of it having been trapped at Shoreham Harbour, and by various groynes to the westward—difficulty was experienced in keeping the bays formed by the groynes sufficiently filled.

The damage to, and occasional destruction of parts of the Seabrook wall between Hythe and Sandgate, arise from the same cause—the liability of the stratum in which it is bedded to scour—and the short timber groynes subsequently added have not altogether remedied the mischief.

At Scarborough ‡ the North Sea Wall (see Fig. 6), 3600 feet long, was built 1886–1890. The foreshore consisted of a layer of sand and gravel, varying from 5 to 2 feet thick, overlying shale which was bared in rough weather. Within twelve months of the completion of the wall, the erosive action of the sea was found in some places to have scooped out the shale to a depth of 3 feet. A stone pitched apron 15 feet wide and 800 yards long, bedded in concrete, was added in 1891.

At Meadfort, Torquay,§ the sea wall was founded on greywacke which was so hard that blasting had to be resorted to, and yet the foundations were undermined 4 feet in depth. The sea removed the rock from the face of the wall below the footings, and so altered the character of that upon which the wall rests that what appeared, when the wall was built, to be solid rock, is now a clay shale, which is utterly unfit to support any weight to resist the action of the sea, even for a few hours.

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* Proc. Municipal and County Engineers' Assoc., vol. xv.

† Dowson, Report British Association Committee Erosion of Coasts, 1888.

‡ Proc. Municipal and County Engineers' Assoc., vol. xviii.

§ Ibid., vol. xi.

A wall built in steps such as at Margate (see Fig. 7), while it does not prevent scour in heavy storms, appears to the author to be the best form. The body of water is broken as it strikes the wall, so that it is not projected upwards to the same extent, and the return to the shore is retarded, so that scour is diminished.

The foregoing examples have been adduced to show that the foundations of nearly all sea walls, whatever the form of the wall may be, where much exposed yield in time to the resistless scour brought to bear upon them, and the walls are inevitably undermined and the surface of the shore lowered, unless they are protected by groynes.

III. *Groynes.*—The author stated at the outset that drifting sand and shingle are the most important elements to be considered in preventing the encroachment of the sea. The function of a groyne on the sea shore is to deflect the waves, so that the shingle, &c., transported by them may be deposited and retained in the vicinity of the groyne, while the object of the deposition and retention of the shingle, &c., is to gradually raise the level of the beach and foreshore. The height to which it is intended to ultimately raise the groyne should be so adjusted as while retaining sufficient drift to stop the run of the waves, the surplus may be allowed to pass on for the protection of the shore to leeward. The groyne should be long enough to prevent the sand and shingle passing its lower end too readily, for if too short, the waves during on-shore gales drawing the shingle, &c., down from the beach will carry it to leeward, so as to partially deplete the bay formed by the groyne.

It is often expected that the erection of a groyne will immediately create a beach. But groynes will only arrest that which is travelling along the shore, and they do this at a rate depending upon the supply of the drift. It may be small or great, so that the bay, or bays, formed by the groynes, may not be filled for some years or they may be filled in a short time, before the beach has accumulated to such a height as to check further inroads of the sea. A series of groynes for instance, will require a longer time to fill than a single groyne, for the reason that in the former case the bay, or bays, to leeward need their share of sand and shingle, while if the condition of the leeside may be disregarded, a single groyne may be built or planked up to its ultimate height very quickly. It is always most important that groynes, if of timber, should be planked up only as the shingle, &c., accumulate against them.

The effect of the interception of the drift is strikingly seen at the fine masonry groyne built by the late Sir John Coode at the east end of the Hastings frontage. On the west side of the groyne a large quantity of shingle has accumulated, forming a safe and extensive beach for the fishermen's boats; but on the east side of the groyne there is deep water and the rocky shore is bare. The cliffs, however, being high and of rock, no harm is done.

It will be interesting at this point to refer to what has been done, apparently with much success, on the Ligurian coast of Italy. And here the author quotes from the Minutes of Proceedings of the Maritime Congress of 1893.

"The most noteworthy of all the works undertaken are those on the railway from Genoa to Ventimiglia along the beach at Cornigliano. The beach, the direction of which is E. ¾ S., was considerably eroded for a length of about 800 metres by the violence of the waves under the prevailing S.W. wind. Every winter the line was much damaged. An attempt was made to protect the bank by a massive longitudinal sea wall, but the sea gradually undermined the wall, and the structure slowly disappeared in the sand. M. Parodi having been consulted, advised the construction of a series of groynes, and this course it was decided to adopt. From 1884 to 1892 four groynes were constructed, covering a distance of about 550 metres, and at respective intervals of 103, 248, and 195 metres, and lengths increasing from west to east of 30, 65, 70, and 112 metres, with a depth of water at the head from 3·25 to 5 metres.

"After the execution of these works, the railway received no further injury. The diminution of the beach was stopped, and at present there is every tendency to increase; the submerged slope being silted up, small banks forming at each groyne, and a beach 50 metres wide being deposited on the eastern side of the groyne nearest to the mouth of the Polcevera, from which most of the material is conveyed.

"The effect is less conspicuous on the other groynes; and it is evident that this groyne, which is of much greater length —112 metres—than the others and extends into a depth of 5 metres of water, projects too far relatively to the neutral line of the south-east waves which chiefly bring the suspended materials to the beach from the Polcevera and which has a maximum height of about 2 metres. This groyne therefore checks the regular spreading of the material and hinders the filling up of the beach on the western side of the structure."

The conclusions arrived at by the Italian Maritime Hydraulic Engineers are:—

"1. Groynes are the best form of structure by which a beach can be protected from erosion, provided that there is a sufficient quantity of suspended material brought to shore to replenish the surface.

"2. If it is required to raise or extend any length of beach, the groynes must not be carried out too far, i.e., they must stop short of the neutral line, corresponding to those waves that cause the greatest amount of materials to move along the beach.

"3. If it is desired to increase the beach at one point only or for a relatively short distance, it is necessary to construct one groyne of sufficient length to extend beyond the neutral line.

"4. As it is often difficult to determine which are the waves that cause the maximum quantity of material to move along the shore, it is advisable to curtail the length of the groynes until experience has shown for each one individually to what extent it is necessary to prolong them.

"5. As groynes should be able to withstand any yielding of foundation without damage, it is better to construct them of rubble stone than of masonry or concrete."

It is important to observe that, on the coast referred to, the rise of tide is very small, and as it appears, the material transported by the waves is derived from the matter brought down by the rivers discharging into the Gulf of Genoa. But the evidence afforded by the perusal of the paper from which the foregoing extracts have been made seems conclusive on the points—

1st. That the drifting of the materials along the shore is caused by the wind waves, and

2nd. That in certain situations groynes are better adapted to protect the coast than a longitudinal wall.

The timber groynes built by Mr. R. Pickwell at Withersea, on the Yorkshire coast, in 1870–71, by arresting a large quantity of shingle and sand, stopped the erosion of the cliffs, and the overflow of the sea on to the low-lying land. The trend of the coast there is north-west, and there is no great projecting point or harbour to intercept the passage of the great quantity of drift derived from the waste of a long length of coast. The groynes varied from 300 to 350 feet in length, and were fixed 200 yards apart, at right angles to the coast line. The top ends were fixed 12 feet above H.W.O.S.T., and the lower end 6 feet below that level, or from 3 to 4 feet above the then surface of the shore. The top five rows of planks were added only as the beach grew. The groynes when completed stood from 8 to 10 feet above the level of the high beach, and from 4 to 6 feet above that of the lower beach. In 1876 four of the groynes at the south end were completely buried, and the other two for two-thirds of their length. The ordinary high water spring tide mark was from 50 to 80 yards further seaward.

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* Min. Proc. Inst. C.E., vol. li.

For some years the author's firm has been engaged in constructing timber groynes on the south coast, particularly in Middleton Parish east of Bognor, and between Lancing and Shoreham, over a length of coast about 2½ miles. The coast line at the former place faces nearly due south, and at the latter S.S.E., and both are exposed to the full force of south-west gales. At Middleton the shore, for want of adequate protection, had become almost entirely denuded of shingle when the author took charge. The supply of drift is not large, as quantities are deposited and retained opposite Pagham Harbour, about 6 miles to the west, under the lee of Selsea Bill. The groynes erected in 1889 and 1890 have arrested a large quantity of sand and shingle, so that the property, part of which is below the level of high water spring tides, is now protected as far as the groynes extend. At Lancing there is a fair supply, as, except the Worthing groynes, practically there is little to intercept the drift between it and Middleton, a distance of about 13 miles.

The general design of the groynes at these places is similar to those erected by Mr. R. Pickwell, although they differ in details. They are about 270 to 300 feet long, and from 400 to 500 feet apart. The height at the top end is 8 feet above H.W.O.S.T., and at the lower end 10 feet below that level, or, when first fixed, from 3 to 4 feet above the level of the shore. Similarly to a portion of the length of the coast with which Mr. Pickwell had to deal, the beach, both at Middleton and Lancing, forms a bank or ridge of shingle, which protects the low-lying land behind—in the case of Lancing about 600 acres. In storms these ridges were swept back, and the sea was encroaching opposite the village of Lancing at the average rate of about 18 feet per annum. The top of the ridge from Lancing to Shoreham for about 2 miles in length varied from 7 to 9 feet above H.W.O.S.T. In either case the expense of a sea wall, or any breastwork, which would have also involved groynes, was not to be thought of, as, except opposite the village of Lancing, the land to be protected was agricultural.

The first set of groynes (see Figs. 8 and 11), 16 in number, between Lancing and Shoreham, was erected in 1876–1877. In addition to the groynes, a small shingle bank, the top of which was 3 feet wide and 10 feet above H.W.O.S.T., was formed from 30 to 50 feet back from the upper ends of the groynes along the top of the shingle ridge, to stop the run of the spent waves in strong gales. These groynes and bank have for the last twenty years entirely prevented further encroachment of the sea, which, in 1876, seriously threatened the property. In 1892 the author's firm constructed a set of groynes further west, commencing at the west corner of the well-known gap in the road between Lancing and Worthing; and, in the present year, the first set of the groynes having become worn out, they are replaced by new ones. The width of the top of the shingle bank in the last two cases has been made 10 feet instead of 3 feet. All these groynes are erected on the same principle, the direction of the old set pointing S.E. by S., and of the new S.E. In this respect they differ essentially from the groynes built by Mr. Pickwell, and from the practice on other parts of the coast.

Seeing the conflict of opinion upon this point, the author may be permitted to advance some considerations respecting it. The view he holds is by no means new, but it has been tried and found successful.

The late Mr. John Thornhill Harrison, after much practical study of the subject of the motion of shingle and sand, &c., on the English coast, recorded in 1848 * his opinion that " a groyne run out in a slanting direction from the prevailing winds appears the most favourable. The power of the prevailing waves to sweep out the shingle from behind the groyne, and to carry it forward, would be much diminished, and they could only act on the beach some little distance beyond the groyne. On the other hand, it would encourage the accumulation behind it of shingle driven by the waves from other quarters, whilst as these impinged on the groyne on the outer side, they would exercise considerable power in carrying the shingle back."

In the following year Mr. Harrison † emphasised this opinion as follows:—" The run of the tides produced very little effect upon the beaches at Dawlish and Teignmouth. The waves were the chief cause of the shingle shifting, and as the south-west was the prevailing wind, the waves raised by it drove the shingle along the coast to the eastward, causing an accumulation against the western side of the groin, and, unless they were carefully placed, laying bare the eastern side to the foundation, and causing a run along the wall or coast they were intended to protect. The direction of the groynes should be at a considerable angle to that of the prevailing winds, so as to allow the waves spreading out like a fan, and so depositing any shingle that might be carried with them."

Lieut.-Col. Gordon, R.E.,‡ in 1853, after ten years' observation of the coast at Eastbourne and Hythe, came to the conclusion that groynes ought not to be constructed perpendicular to, or in immediate contact with, the work they are intended to protect, but that they ought to be *en échelon* to the periodical high seas and winds; that is to say, the sea should strike upon and wash over a groyne in an oblique direction, with the obtuse angle formed by the groyne and the wave on the land side, so that the sea on its recession should leave the ejected sand and shingle on the opposite side of the groyne. The diagram illustrating Lieut.-Col. Gordon's paper shows the direction to be an obtuse angle of about 103° with the S.W. wind.

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* Min. Proc. Inst. C.E., vol. vii.

† Ibid., vol. viii.

‡ Professional Papers Royal Engineers, vol. iii. new series.

As will be seen, the direction of the groynes at Middleton and Lancing has been laid consistently with the conclusions of these authorities. After twenty years' experience, the author is satisfied that groynes laid in such a direction are more effective in accumulating and retaining drift than those laid in any other.

Mr. Edward Case, A.M.I.C.E., has designed and patented a system of groynes differing, in mode of application and detail, from the examples already described, and has adopted them for the preservation of the Dymchurch wall, and of the frontage of the New Romney Level. The shore from Romney Hoy to Dymchurch trends to the north and north-east, and is under the lee of Dungeness, so that it is sheltered from the south-west gales. The wind, which drives in the sea with the greatest effect on that shore, comes from the south-east. Here, only sand seems to be accumulating on the foreshore, the greater part of the shingle being intercepted by Dungeness. Mud has hitherto collected on the shore, and a deposit of mud is shown on the Admiralty chart, close to the north point of Roar Bank, at a depth of 2¼ fathoms. From this circumstance it does not appear that strong currents prevail, nor that there can be so much scour along that part of the coast as at other points.

The Dymchurch wall has already been referred to, and its front slope described. The stone wall is backed by an earth bank, which defends the low level of Romney Marsh from overflow by the sea. In 1894, Messrs. Mathews and Wolfe Barry reported on the state of the wall, which was then in a dangerous condition, and recommended the construction of a number of timber groynes along the frontage. From the bad condition of a considerable portion of the width of the lower portion of the pitched slope, Mr. Case removed a good deal of it, and temporarily constructed concrete steps, with a concrete toe, a short distance down the slope. He subsequently erected long, low groynes on his system, commencing at the foot of the shortened slope, and adding to the height of the groynes as the sand accumulated. He thus raised the level of the foreshore in some places as much as 8 feet, in this way quite protecting the pitched slope. When the author saw the shore it formed a fine stretch of sand.

There is no stone pitched slope or wall on the New Romney frontage (see Fig. 10), the beach of which has its top from 6 to 7 feet above H.W.O.S.T., sloping at an inclination of 1 in 9 down to a flat foreshore of sand having an inclination of about 1 in 60. At the back of the beach there is a breadth of sand-hills which, although the sea has encroached upon them at the rate of 8 feet per annum, prevent overflow on to the low land of Romney Level. On this foreshore a good deal of sand has already been accumulated by the eleven groynes put up by Mr. Case, each of them 420 feet long, and 500 feet apart at right angles to the coast line.

It may be remarked that Mr. Case differs from other engineers, not only in detail but in commencing the upper ends of his groynes at the level of Ordnance Datum, or about 10 feet below H.W.O.S.T., or approximately at the foot of the steep slope of the beach where the flat foreshore begins, and extends as far out to low water as practicable; that is to say, he begins his groynes where, in most cases, they leave off. The upper part of the beach is therefore for the time left unprotected. The sand on the foreshore accumulates at the rate of about 2 feet per annum against the groynes, which are not raised more than two or three deals above the shore. In this way Mr. Case expects to gradually raise the foreshore for a long distance towards low water, and with it the level of the beach, and so diminish the depth of water and the power of the waves to scour and encroach.

Mr. A. T. Walmisley* considers that groynes should be carried up to the top of the beach. He says, "It is very essential to the success of a groyne that the sea, not the beach, may wash over the top in rough weather, and that it be carried well up into the full of the beach." The mode of construction of Mr. Case's groynes is fully described in the specification of the patent, and appears simple and inexpensive. The author has not yet seen this system applied to a coast exposed to the full force of gales from the prevailing quarter, but he agrees with Mr. Walmisley that the groynes should be carried up to the full of the beach, where there is no stone pitched slope or wall to protect the frontage.

The points to which the author desires to invite especial attention are:—

1. The protection of the coast line is in most cases dependent on the sand and shingle that can be arrested and retained in front of it.

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* Proc. Municipal and County Engineers, 1897.

2. Groynes, unless there is a foundation of rock, are in most exposed places indispensable, whether there is a sea wall or not.

3. Where there is a sufficient supply of drift along any part of the coast, groynes alone, if properly planned, will prevent further enroachment without a sea wall or breastwork.

In support of the second point he has brought forward the examples of the frontages of Brighton, Hastings and Seabrook, and no doubt others could be mentioned.

The third point he has illustrated by the examples on the Italian coast, at Withernsea, Middleton and Lancing, to which may be added the frontage of Worthing, which is entirely protected by groynes without a sea wall.

It is almost needless to say that the great hindrance to the adoption of any kind of effectual protection against the encroachment of the sea, except for residential property, is the cost. No frontage of agricultural land, except where a considerable area is below the level of high water, can bear the cost of any substantial form of defence hitherto devised. It is cheaper to sacrifice the land.

If Mr. Case's system admitted of general application much might be done which so far has not been possible. The cost of such defences falls entirely upon the owners of the frontage, the owners of the back land being content to wait till they in turn become liable. Manifestly the whole burden of liability ought not to be thrown upon the frontagers, while other owners escape scot free, although it would be difficult to devise a graduated scale of rating to meet the case.

The question is a national one, and the Government is much interested in the matter. Coast-guards stations, as well as other works, are established every two miles or so along the coast, and the abandonment of stations and their re-erection further inland owing to the encroachment of the sea are of constant occurrence.

DISCUSSION.

The President said that the subject which had been dealt with by Mr. Grantham in a very interesting paper was, as the author had remarked in his concluding words, one of national importance. The protection of our coast line afforded a great field for engineers, and as it was a question upon which there was a great divergence of views, he hoped the paper would lead to a profitable discussion. On behalf of the Society he thanked

Mr. Grantham for the trouble which he had taken in preparing such an excellent set of diagrams. He would ask the Society to accord in the usual way, namely, by acclamation, a vote of thanks to Mr. Grantham for the paper.

The vote of thanks was unanimously accorded.

Professor VERNON-HARCOURT said he was sure that the members must have listened with great interest to Mr. Grantham's paper, because it was so very clear in showing the difference in value of groynes and upright walls as methods for protecting coasts from erosion. He thought that every one would agree that upright walls would not serve really to protect the coast in a thorough manner; and he imagined that upright walls were mainly chosen for the purpose of enabling a promenade to be made at the places where they were used; but he did not think that a wall in steps, like that which was shown as existing at Margate, would present so pleasing an appearance as a wall either upright or with a curved face. He quite agreed that a wall like the one at Margate would be better for the purpose of preventing the sea from undermining the foundation than an upright or curved wall, owing to the steps checking the downward rush of the retreating waves. An upright wall presented a great difficulty in dealing with the question of encroachment, on account of the amount of scouring that must take place at the base from the backlash of the waves. Nevertheless, an upright wall combined with groynes would give the protection needed, and also enable a promenade to be made. That would seem to be the suitable course in the case of towns which required to have a promenade made for the purpose of recreation. In other cases groynes made in the cheapest manner possible were the only works which the cost would enable engineers to think of. In this country the value of agricultural land was a great deal less than it formerly was, and therefore they could not resort to expensive measures for protecting it. He quite agreed that groynes should be made slanting, and not at right angles to the coast, and at a certain angle with regard to the direction of the prevailing winds. He also agreed with the author in thinking that the drift of the material along the coast was due to the direction of the strongest winds acting through the medium of the waves. That was quite clear from what had been stated with regard to the Ligurian coast of Italy. Last year, moreover, he had an opportunity of seeing the accumulation of sand at Port Said against the west side of the west breakwater which protected the harbour. The rise of the tide there was insignificant, and the prevailing winds were in that case from the west, causing an eastward travel of sand and silt which was partially arrested by the breakwater. An important question was, how much material was being brought along the coast, which might vary from time to time. He had known a beach near Torquay where the drift of shingle depended very much upon the quarrying in the vicinity. When quarrying was carried on, a great deal of refuse stone was thrown over the cliffs, and there was a great deal of shingle travelling along the shore.

Mr. W. Whitaker, F.R.S., said that, not being an engineer, he must ask pardon if he inadvertently said things which might seem very incorrect to engineers. On those matters as to which he had the slightest right to say anything he agreed very much with the author. He ventured to differ from the author only on certain points upon which it was comparatively impertinent for him to speak. He thought, for instance, that the author was quite right in saying that the varying conditions of the coast were not enough to account for the different treatment that had been adopted, and he ventured to think that the ingenuity of engineers was one of the causes of the great difference. He must protest against any engineer calling a wall at 45 degrees upright. Of course it was very useful to employ words in that way, because any objection to an upright wall would be abolished if walls at various angles were included, and it would do away with more than half the opponents of an upright system. In the list of coasts at which losses had gone on the author had included a great deal which he (Mr. Whitaker) knew very well, and had in some cases measured. For instance, just to the north of Fig. 3 there was a cliff of which fifty or sixty feet went in a year. We were now in a much more favourable position to record the state of the coast than we were formerly, from the fact that there now existed detailed accurate Ordnance maps, which showed the state of the coast as surveyed at a definite time. He had been rather astonished at seeing how soon the coast line became different from the state of it as shown on a comparatively new map. He was very glad that the author noted so strongly that the sand and shingle along the shore were the great protection of the coast. He had no doubt that the taking away of the sand and shingle was, in most cases, an absolute evil, because, although there might be too much at the spot from which it was taken, there were other parts which wanted all that could be sent to them. This emphasised a point which perhaps engineers had occasionally overlooked, which was that they should follow Nature as much as they could. Nature had provided the best protection for the coast, and what the engineer had to do was to keep that protection and apply it judiciously.

Nature had sometimes given too much protection in one place and not enough in another, and what was required was that the protecting material should be properly distributed.

He thought that Mr. Grantham had shown himself very wise in speaking of Canvey Island, because it was an out-of-the-way place which hardly anybody had been to, and so a person might say what he liked about it. He believed that the walls were really a great deal older than they were said to be. He presumed that they were the same age as certain others along the estuary of the Thames, some of which he believed to be Roman. It seemed to him to be somewhat of a mistake to make a vertical wall, as it appeared to absolutely oppose Nature. If they said to Nature, "You shall not come here," or "You shall not do this or that," Nature as a rule replied, "I will do it." He thought that a wall which gave a slight guidance to the waves instead of an abrupt opposition to them was likely in most cases to be the greatest success. Mr. Vernon Harcourt had spoken about the Margate wall not being very pretty. He (Mr. Whitaker) was inclined to think that that was rather an argument against it, for when Nature did anything she nearly always made it uncommonly pretty. There was not the slightest occasion to be ugly. At the same time he was not at all sure that the wall spoken of was ugly. He did not remember it, although he had often seen it; but anyway the irregularities must have the effect of breaking the waves. As the author had said, they must study the actual conditions of each individual case. It could not be expected that one general rule would apply in all instances. Possibly in some places a nearly vertical wall was best, while in others an inclined or broken wall was best.

The allusion to a temporary failure of the wall at Westgate was very good. The records of failures, whether partial or total, were far more instructive in such matters as this than the records of successes, and it was much more important that engineers should know where the weak points of a scheme were than that they should know the strong ones. Anybody could find out the good points quickly enough. He was very glad to find that engineers did not hesitate to point out where a mistake had been made. The rock at Torquay which had been alluded to was only hardened clay, and one could understand that, under certain conditions, it might to a certain extent become more or less soft. With regard to groynes, of course such structures were the great thing for the defence of the coast, and they were simply an imitation of Nature. A groyne was an artificial obstruction made by following the course which Nature took to stop the too quick flow of the beach. The shingle, however, might be stopped too much. There was a remarkable case at Newhaven where shingle had accumulated very largely. The shingle had not crossed the river, and a wall or embankment between Newhaven and Seaford had gone pretty nearly the whole way. The sea had undermined it, and carried it away. He believed that it had been rebuilt more as an earthwork. At Folkestone there was another case. The harbour had banked the shingle up and prevented its going along to Dover, and consequently there were landslips along the coast between.

The author had spoken of the difficulty of cost in connection with the protection of the coast. The way to get over that difficulty was the same as that which was adopted with regard to many other difficulties, namely combination. What was wanted in many cases was a combination of authorities along a great length of coast, in order that the work might be done properly, and for the purpose of preventing one locality doing work for itself, without regard to the effect of the work upon neighbouring places.

Mr. A. T. Walmisley agreed that the subject of the paper was of the greatest interest, and that the paper itself was a very valuable one. He had, however, noticed that the only diagram which showed the line of low water level was that marked No. 10, the one illustrating the new Romney level. But the position of low water was in his opinion of very great importance in connection with sea defences, and in considering the protection of the foreshore by means of groynes, for not only should a groyne be carried well up, but, as the author had said, it should be made long enough to prevent the sand or shingle passing its lower end too readily. He agreed with Mr. Whitaker's remark that in arranging defensive works isolated action was undesirable, and that adjacent owners should combine to carry out a uniform plan. It had been argued that a groyne ought not to stop too much material, but with regard to that matter he would call attention to the well-known history of Sandgate. The cause of the disaster which took place there a short time ago was well known, and it would be remembered that in that case the wall had a shallow foundation and was protected by short groynes. In his opinion the groynes ought to have been carried further out to sea, because during an extra low water spring tide a good deal of the shingle was lost and the wall became undermined. He thought that it was very important to carry the groynes well out into low water. That had been done at Dover, and he believed that the absence of anxiety as to the foreshore at that place was due to that fact. The mode of construction illustrated in Fig. 10, for which Mr. Case was responsible, was admirable, and possessed the merit of economy.

Perhaps it did not admit of general application, but it would certainly admit of greater application than had been made of it. He had had an opportunity of seeing how the foreshore at Romney Marsh had increased in height, and how the sand had accumulated upon the foreshore, enabling Mr. Case to carry up each groyne; and he knew that Mr. Case had availed himself of the low water spring tides to extend the groynes seawards. That was a very essential feature.

With reference to a vertical wall, he knew a case of such a wall constructed of timber backed with raking piles supporting the timber face and retaining beach at the back. When the sea came against the vertical wall it transmitted a vibration to a considerable distance inland; whereas in the same situation not very far off, where there was a masonry wall, no vibration was felt. Where there was a promenade between the residential property and the sea a curved face wall was in his opinion best, but he did not think it would tend to contribute more beach than a vertical wall. As regarded the form of groyne to be employed, that must doubtless depend upon the locality. A groyne was simply a screen to collect the beach. He supposed that the groynes in Fig. 11 were placed at the angle there shown in order that they might bring up the beach at right angles to themselves. A great deal depended upon situation. What would answer in one place might not answer in another.

The author had alluded to the wall up to which the groynes ran. He (Mr. Walmisley) failed to understand the remark of one authority which the author had quoted, and which spoke of the wall not being connected to the work that was to be protected. He should have thought that the groyne ought to be connected to the foreshore which it had to protect, or carried well up to the full of the beach. With regard to the wall up to which the groynes reached, he had known cases in which the line in plan of the wall had presented a sort of saw edge in its longitudinal coping and supporting material. That, to his mind, was wrong. The line in plan ought to be very carefully considered. The direction of the wall should be such that when the waves struck it, they should be deflected, and not tend to work their way in. If there was a wall with an entering angle there would be some mischief at the angle at which the sea acted powerfully against it. There should be a flattening off, so that the waves might be deflected. In conclusion, he emphasised the importance of carrying the groynes well down to low water level.

Mr. W. H. Wheeler said there were no engineering works in which so much moneywas wasted as in those provided for the protection of the sea coast. A practical paper like the present, which laid down the principles of the subject, was of exceeding value. He had been mentioned in the paper as holding the view that the travel of the shingle was due, not to the wind, but to the tide. If Mr. Grantham's view was correct that the amount of the shingle was due to the wind, and that the object of a groyne was to deflect the waves, the groyne ought to be of a much more substantial character. He held that the movement of drift was regular and continuous, and with few exceptions was always going in one direction. An occasional wind might reverse the action for a short time. It was admitted that shingle always travelled in one direction along the coast, which was invariably that in which the flood tide moved. While the movement of drift was regular and continuous, the action of the prevailing wind was intermittent and occasional. In England the winds came from the south-west during two-thirds of the year, but the movement of the drift round the coast varied in every part. On the south-east coast the shingle travelled in three different directions, though in such a limited area the wind could only be in one direction. In some of the principal bays on the south coast the shingle was found to travel in two opposite directions. As to the dominant winds, he would admit that they made the greatest waves and caused the greatest erosion. They did not, however, build up the shingle. They did exactly the opposite, for they tore it out. It would be found that by an on-shore wind the whole of the shingle was carried out, and if the groynes were not carried far enough, the shingle would be carried beyond them. When the dominant wind turned and a calm came, the shingle travelled back up the beach and formed those banks which everybody knew so well. The same thing took place when the wind was off shore. It was the tidal action that built up the beaches. He had never yet seen a sea in which there was not a continual succession of small waves coming in; and though these might not be more than nine inches or a foot in height, they were quite sufficient to lift pebbles of considerable size to the top of the bank and leave them there. He believed that if people would put aside their old prejudices and quietly examine for themselves, they would be convinced that the regular and continuous movement of the drift was due to the tide. If that was so, all that had to be done was to put in low light groynes sufficient to hold the drift and prevent its travelling forward, and gradually to raise them in the manner described in the paper.

As Mr. Whitaker had said, they must help Nature to protect the coasts for them. Nature provided the material for building up the beach and making the waves shallow, so that they had less effect in the eroding process. There was no such thing as creating drift. If they had no cliffs they would have no shingle or sand. The material did not come from the sea, but came entirely from the land, and all they had to do in protecting their coast was to take care of the material. A mistake which was often made was to put groynes much too close together. He was not speaking dogmatically, but was simply referring to what he had observed in going round the coast. The case of Folkestone illustrated the advantage of groynes placed at considerable distances apart. At the east end the wall protecting the harbour, which was built about fifteen years ago, ran out a considerable distance from the shore, its direction sloping away from the run of the drift. After its construction, the waves striking against the wall at high water, eddied round and cut out the shingle as fast as it collected and carried it into the harbour. A stone groyne was then run out on the west side of the wall at right angles to the shore. Since that had been done the shingle had collected along the beach in great quantities. The old groynes which had been placed along the shore at intervals were now buried, and for about half a mile there was a fine level beach of great convenience to visitors for walking, bathing, and other purposes. Further west, at Seabrook, an example of exactly the opposite character was to be found. A long sea wall with promenade at the back was built there a few years ago, and for its protection a number of groynes were run out at right angles and at short intervals apart. Those groynes were raised a great height above the beach. For about two-thirds of the length the shingle had collected at the west side of the groynes, leaving the shore nearly bare on the east side, so that there was a drop from one side of the groyne to the other of from 6 to 9 feet and even more, rendering the beach perfectly useless for walking, bathing, or other seaside purposes. The supply of shingle had not been sufficient to fill up the beach between the groynes at the east end, and consequently the waves broke with great force on the sea wall and in places had broken it down. If the groynes had been placed further apart and kept lower the shingle would have been more evenly distributed over the whole length and the sea wall fully protected. This was proved by what had taken place along the beach at Hythe, which adjoins Seabrook on the west. There a single groyne run out nearly to low water at the east end of the sea wall had caused the shingle to collect all along the beach for a very considerable distance, and to within two or three feet of the top of the sea wall, affording ample protection to it and leaving a beautiful level strand.

The argument which he wished to establish was, that groynes should be gradually built up, should not be carried very high, and should not be put too closely together. The action of Nature should be closely followed, the great object of which was to build up a beach so that the waves might expend themselves upon the shingle instead of upon the cliffs.

Mr. **Edward Case** said the subject was one in which he took a deep interest, and he had listened to the paper with great pleasure. He had had to fight the sea at Dymchurch for some years past. In the winter of 1893–4 the Dymchurch wall was in such a perilous condition that everybody thought that the sea would break through into the marsh. The wall was, no doubt, originally placed behind a full of beach. The beach gradually disappeared. The wall was originally paved for a certain distance down. As it became undermined it was gradually extended seaward, until in 1890 the foot of the wall had been carried so low down that it was not possible to get at it for repairs except in the summer. The author had referred to his (Mr. Case's) having abandoned the wall. The fact of the matter was that the sea broke up the east end of the wall, and destroyed about 40,000 square yards of paving, which would have cost 20,000*l.* to replace. He found in 1890 that since the Ordnance Survey of 1872 was made, the low water mark had advanced 300 feet towards the foot of the wall, and the sea had encroached east and west of the wall. There was only one of three things to be done. One was to push the low water mark back again to where it was before. Another was to set the wall further inland, which would have cost an enormous sum of money. And the third was to build a monolithic structure which would resist the deep water which had been brought in against it. Perhaps the author would forgive him for correcting him in one or two minor details with regard to the Dymchurch wall. The top of the wall was 12 to 13 feet above high water mark, at ordinary spring tides. The slope of the wall varied from 6 to 7 to 1 at the top, to 5 to 6 lower down, and the foot of the slope was 4 to 1. The apron at the east end of the wall was 140 feet wide, and 80 feet wide at the west end. In 1894 he started pushing out very low groynes at the east end where the damage had been done. In no case did they stand more than 3 feet 6 inches to 4 feet out of the foreshore. They reached low water mark at 110 feet. The following equinoctial tides he found the groynes had created sand seaward and the water was shallower. Now some of the groynes were over 500 feet in length. The effect had been that the low water mark had been pushed back 400 feet in three years, and at the foot of the wall a depth of no less than 8 feet of sand had been collected.

The author had alluded to the starting of the groynes. When he commenced in 1894, he held the same opinion as other engineers appeared to hold, namely, that the groynes should go up the beach inclined to high water mark; but his observation of the works at Dymchurch had shown him that, as a rule, if they had high groynes, or groynes running up to the full, they could not collect the material equally on both sides. They must attack the enemy lower down, and gradually lead the sea up and let it expend its force when it got to high water. The form of the groyne was a very important point. All groynes which he had seen put up had a uniform inclination, generally of about 1 in 10, but no foreshore in the world would stand at that angle. The natural inclination of a foreshore was an ellipse. If the section of a foreshore was taken after a gale of wind it would be found to be almost a perfect ellipse. The subject was an important one for engineers, for there was no doubt that the encroachment of the sea at the present time demanded serious attention not only at the hands of public bodies, but from all landowners.

Mr. PERRY F. NURSEY observed that Mr. Whitaker was quite right in saying that Canvey Island was such an out-of-the-way place that Mr. Grantham might say anything he liked about it without fear of contradiction. He (the speaker) knew the district well, and endorsed all that Mr. Grantham said about it. The soil of the country on the coast line was alluvial, and was always giving trouble, being very treacherous. In 1874 he built eight sunk magazines and a wharf upon a plot of land at Benfleet, bordering on the creek, and to the rear of Canvey. In order to test the ground he had an open cut 10 feet wide made 20 feet into the side of a hill on the site of the intended magazines. The cut was made in the autumn before the work was commenced, and after a severe winter the faces of the cutting were absolutely intact, with the exception of a very slight surface weathering of the soil. On starting the excavations for the magazines, however, pipes of sand were encountered in several instances, which formed leaders for the land water, so that the soil had to be well timbered up during construction, and provision had to be made for land draining, which had previously been considered unnecessary both by himself and the contractors. In fact the soil all round was very treacherous, as Mr. Grantham had doubtless experienced.

Upon one occasion he (the speaker) had a very narrow escape of swamping, not merely 1500 acres but possibly 15,000 acres, owing to the failure of one of his sea walls. That was due to a wash-out of the subsoil; but fortunately it occurred at low water, and labour being at hand, the breach was repaired before the water got in. Towards the last, however, it was a fight with the water, but with a local foreman skilled in wall work, backed by good labour, a serious inundation was prevented.

He might refer to a remarkable natural coast defence with which he was acquainted, and which was known as Pebble Ridge. It was situated at Westward Ho, Devon, and formed a protection to Northam Burrows, a large tract of low-lying land immediately behind it. The ridge was composed of boulders of all sizes, some very large, which were washed up by the Atlantic, forming a high and broad curved embankment, similar to a railway bank in cross section, and extending along the coast for over a mile, He was informed that ships were constantly taking ballast from the northern end of the ridge, but that the deficiency was always being made good by fresh boulders being washed up by the sea, which was very rough on that coast.

Mr. R. St. George Moore said that while others had been examining and watching the coast on a large scale, he had been practically examining it with the microscope, with a view to prevent the sand and shingle accumulating on the permanent way of the seashore railway at Brighton. He would describe the result of his observations, which did not, as he understood it, accord with Mr. Wheeler's theory as to the movement of sand and shingle along the coast. After a certain number of days of south-east winds, the invariable result was that their line was blocked with sand; that was to say, the wind, acting against the flowing tide and with the ebbing tide, caused the sand to move directly against the flowing tide, but directly the wind changed to the south-west, and acted with the flowing tide, the sandbank was driven to the eastward. The movement of the sand and shingle was directly as the direction of the wind, and therefore, inasmuch as the prevalent wind was from the south-west, and in the same direction as the flowing tide, the two forces, acting together, caused a greater movement of the sand and shingle to the eastward than to the westward. From further observations the time of the movement appeared to be just at the time when the water flowed over or receded from a particular portion of the beach. For instance, the flowing tide formed a sandbank over the line. After the sand ploughs attached to the cars had once cleared the road, it would remain clear until the receding tide had nearly reached the level of the line, and then the sand and shingle would be washed back on to the line. That showed that it was the movement of the water, or wave action, just as the tide rose or fell, which caused the sand to move. The depth at which the movement took place depended on the size of the waves.

He should like to refer to the question of upright walls. In 1880, he constructed an upright wall at Bridlington, on the coast of Yorkshire. It was designed by Mr. Clark, who was then his partner. It was vertical, with a bull nose. The foot of the wall was protected by an apron 10 or 12 feet wide, with a toe wall running about 4 feet into the clay. The whole wall was founded on clay, and there were no groynes to cause the beach to accumulate in front of the wall. He had occasion to go there seven or eight years after the wall was built, and he found that there was no tendency to undermining whatever. The apron had completely protected the wall. What had happened since he did not know, but he expected that if anything unpleasant had happened he should have heard of it.

As to groynes, he knew those at Withernsea, described by Mr. Pickwell in his paper, and referred to by Mr. Grantham. They were designed, he believed, by Mr. Clark, who was at that time Mr. Pickwell's senior partner. They were built on the north side of the pier, and they did their work so efficiently that in a very short time the wall, the footing of which they were built to protect, was almost buried in sand. Mr. Grantham had referred to the question of groyning being a national one. There was another question which, he thought, ought to be a national one, and regulated by some public office, and that was the relative length of the groynes. Very wealthy corporations, which had money enough to build enormous groynes, did so, thereby seriously damaging their neighbours' property, and that state of things ought to be rectified. One corporation which he knew had, by means of enormous groynes, done considerable damage, not only to the adjoining landowners, but to some of their own property three-quarters of a mile off, and had to build groynes at a very considerable expense to protect it.

With reference to the question of the Margate wall, he thought that in the discussion the speakers had a little lost sight of the fact that, as a rule, walls at seaside resorts like Margate, Brighton, and so forth, were built so as to form a promenade; therefore a wall which would give a dry promenade would be preferred to a wall which did not stop the spray rising. A curved wall with a bull nose tended to throw the spray back and keep the promenade dry, whereas the wall described as adopted at Margate would not do so. With reference to the strength, stability, and probability of the wall not being damaged by the sea, the Margate wall would undoubtedly stand a better chance than the curved and bull-nosed wall, as it resisted the sea to a lesser degree.

He was very glad to hear several speakers advocate low groynes. As far back as 1885 he advocated the placing of low groynes very near the position which Mr. Grantham had referred to, his idea being to arrest the shingle that was rolled along, and to allow the water to continue its forward travel, and not allow it to flow back and drag the shingle down the beach with it. Another point against high groynes filled only on one side, which had already been mentioned, was the amount of damage done by storms from the exposed direction. Take, for instance, the memorable storm which carried away the Chain Pier at Brighton. The groynes were very heavily laden with shingle on the south-west side, being the result of a long continuance of south-west winds, and exposed on the south-east. The result was that such a severe storm coming from the south-east struck the exposed planking of the groynes, disturbing them, and doing an enormous amount of damage. From that it was evident that a very important object to be aimed at in laying out groynes was to so place them that they would collect beach uniformly along the coast line, and not cause it to heap up on one side only.

Mr. J. W. Woodall said that he had been associated with the author's father in the British Association Committee, which was appointed some years ago to deal with the subject of the paper, and he was glad to find that good work was still going on under the son's auspices. He had been for a great many years a member of the corporation of Scarborough, and the foundation stone of the wall shown in Fig. 6 was laid by him just ten years ago. The wall had stood very well. But still at intervals, when very heavy seas rolled in from the north and the north-east, a very large mass of water was projected over the surface of the wall, and the asphalt paving of the road had been broken for a very considerable distance, and great expense had been entailed in replacing it. With regard to the use of sea walls as promenades, the Margate wall, although its shape was not very pleasing from an architectural point of view, had one very great advantage for a watering place. When children were playing on the beach below, the great difficulty of getting up the curved walls had caused some lamentable accidents on various occasions. With regard to the travel of the shingle along the Yorkshire coast it was to be observed that no fossils embedded in the strata were ever found south of the point where that fossil was found on the beach. The trend of the shingle and the gravel was entirely from north to south, that was, in a line with the flood tide, and, as had been remarked, it was in periods of very fine weather that shingle was deposited along the coast.

Mr. W. P. Morison called attention to a point which did not seem to have been brought forward. He said he would not maintain that groynes were not useful, but one essential feature was to get a good foundation. In the case of the Bridlington coast there was a great difficulty in the foundation because the builders came on to beds of clay with sand intervening, which necessitated going to a very great depth. He merely wished to introduce into the discussion the necessity of having adequate foundations for coast defences. The cost of sea walls was often a very serious consideration for the owners of the foreshore, and he was afraid that it sometimes led them to skimp the foundations.

Mr. R. J. G. Read said it appeared to him that there were two different functions pertaining to the two forms of works described in the paper. The groyne was required to preserve the shingle or the sand running along the coast; and the upright wall protected the shore and cliff from being washed away. In the paper and on the diagrams, the upright wall was shown against the cliff or against the shore, and then groynes were built against it to protect it, as he supposed. Some little time ago he was noticing the form of the pebbles on the Chesil Bank with the waves beating upon them. Although the bank was of the height of 20 or 30 feet, the lower part of it was curved away like the Scarborough wall, and above it were terraces rising up to the top of the bank. Evidently that form corresponded with the forces in the water, because the pebbles were round and very unstable. One speaker had remarked that the Margate wall was the best for the purpose of breaking the backward force of the water. It occurred to him, therefore, that a very good form of section would be made by putting the Margate wall on top of the Scarborough wall; the curve at the bottom leading the wave up, and the steps at the top breaking the backward fall and so reducing the effect of the water in undermining the wall.

The following communication from Mr. A. Dowson of Basingstoke, dated October 30, 1897, was then read.

I first designed and constructed groynes in 1869, and I have since studied the subject from time to time. Fourteen years ago I constructed some open groynes in the estuary of the Ribble, and as these have been thoroughly successful I have since strongly advocated this principle.

In Mr. Grantham's very instructive paper I notice he makes no mention of open groynes. In certain combinations of circumstances, solid groynes, however constructed, and notwithstanding they may have succeeded in accumulating large quantities of beach, are always liable to have this accumulation washed out

Open groynes consist of gratings attached to piles driven into the foreshore, the waves pass freely through them leaving the beach behind, and as there is no backwash (or water which has been arrested, and must of necessity, run down the incline of the foreshore) no beach is washed out. Open groynes also have the advantage of being of small cost, they are not liable to damage as they offer little obstruction to the waves, and they do not cause the serious scouring of the frontage on the side of the groyne away from the wind, which is so common with solid groynes.

My experience has convinced me on the following points, viz. that the best way to protect the sea frontage is to raise the foreshore, and that this is best done with groynes (preferably open). The addition of a sea wall makes the task more difficult. The power of the tide to carry beach is very slight when compared with the action of the waves. The on-shore wind is the one that lowers the foreshore the most.

The general protection of foreshores is of national importance, but this can only be effectually dealt with by adopting a cheap but efficient system of protection, and by giving powers to some authority to make it obligatory on all parties benefiting by the protection to share the cost.

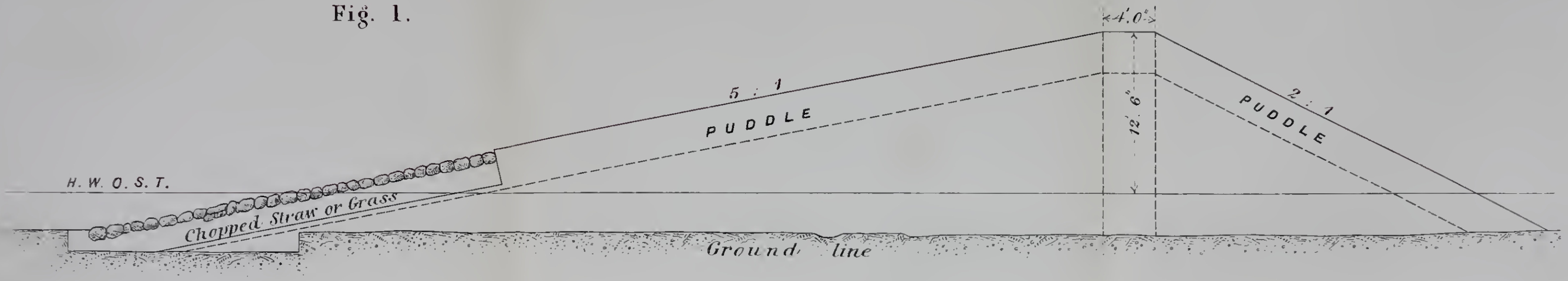
Mr. Richard F. Grantham, replying to the discussion, said he was very much indebted to the speakers for the remarks which they had made and for the information which they had given. He could not understand Mr. Whitaker not knowing Canvey Island, because Canvey Island was once intended as the place of deposit for the London sewage, and very recently it was fully illustrated and described in a daily paper. As to the age of the walls, he had stated in his paper that the history of the maintenance of the walls began only in 1620, but the original walls must have been made very much earlier, possibly, as Mr. Whitaker had said, by the Romans. With regard to the upright walls there was no doubt that, whatever inclination they might have, the waves would shoot up over the top. The only way in which the sea could be prevented from going over, was to put a nosing on the wall and curve the top of the wall a little outwards; but the danger of that method was that the water, as had been stated by Mr. Ellice-Clark, was thrown violently down the shore and created a scour. Where the foundations of a wall were on clay and sand, as had been described by one speaker, it was necessary to have groynes, no matter how far the foundations were carried down. As regarded the particular slope of the wall, of course he was referring in the paper to the profile and not to the bulk of the wall. Ordnance maps showing the tide lines were of great use, and by such maps he had been able to measure the degree in which high-water mark had advanced on a beach.

As to the quantity of material travelling, which Mr. Vernon-Harcourt had referred to, it was extremely difficult to say what it was, but at some places very little shingle came along. As to groynes, all the speakers had agreed that they should be low and that, if of timber, the greatest care ought to be taken not to plank them up until the beach had accumulated. It was never certain that some part of the groyne would not be exposed. For instance, a south-east gale would scour a groyne a little on the west side. Then, if the wind changed to south-west, or south-south-west, a face was exposed; and the object of putting the groyne in the direction described in the paper, as against the right-angle direction, was that in a right-angle direction the waves impinged on the groyne and their force was only partly broken, so that the rest of their power was expended in eventually scouring round the top end of the groyne; while in the direction described their force was broken and scouring power minimised, and the shingle accumulated evenly on both sides of the groyne. He agreed with carrying groynes out as far as possible. He was afraid he could not agree with Mr. Wheeler as to the cause of the movement of the drift. It was quite true that during gales the shingle and sand were drawn downwards, but they were then carried to the leeward; and that action, which coincided with the general movement of the drift, was not caused by the tide. His opinion was confirmed by what took place in the bay formed by Selsea Bill on the west and Beachy Head on the east. In the main channel outside these points the flood tide flowed eastwards until high water; but in the bay, the flood striking Beachy Head turned round to the west, so that one and a quarter hour before high water opposite Rottingdean the flood tide was flowing westwards, and opposite Littlehampton there was a period of two hours of slack tide before high and low water. Whether the same condition applied to other coasts he did not know. He accepted Mr. Case's corrections as to the particulars of the Dymchurch wall, although the author's figures were quoted from Mr. Elliot's paper. The results which Mr. Case had found were very satisfactory indeed, and afforded a very useful lesson, but it was necessary to wait until the drift rose before there was sufficient protection. He agreed with the view that Government would not take up the question of sea defences, although it was a national one. The only way in which such defences could be carried out would be by combination among the local authorities on different parts of the coast, or by creating commissions of sewers. There were, for instance, commissioners of sewers for the west part of the coast of Sussex which included Bognor, and he thought that some defence might usefully be maintained along the coast line by such bodies.

In conclusion, he must thank Mr. Whitaker for his very kind reference to his (Mr. Grantham's) father. Mr. Whitaker's remarks were a very great encouragement. He wished also to thank Mr. Case for lending him tracings from which the diagram was taken, and Mr. Albert Latham, of Margate, for information.

ESTUARY OF THE NENE.

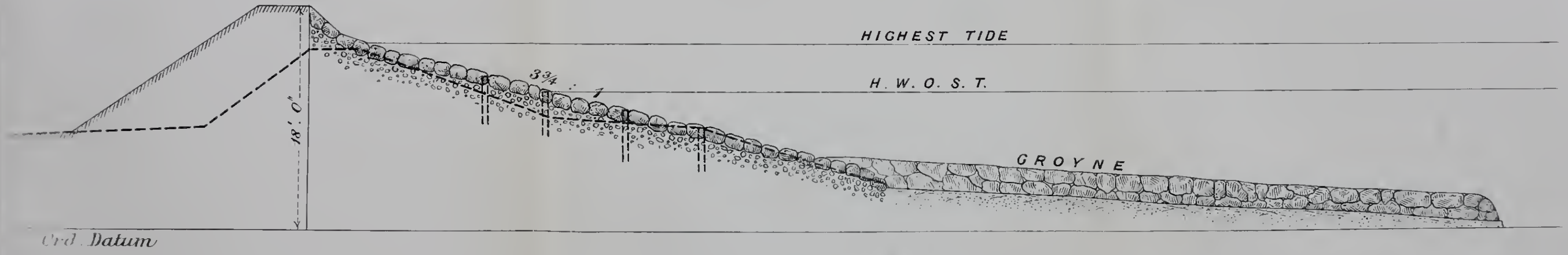
Fig. 1.



CANVEY ISLAND.

FRONT WALL.

Fig. 2.



Scale for Figs. 1-7. 10 ft to an Inch.

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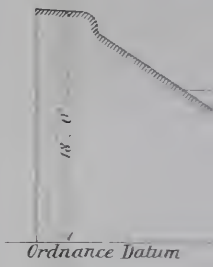

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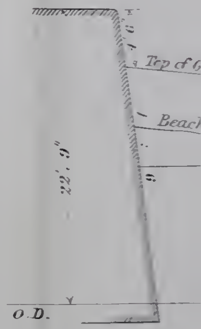

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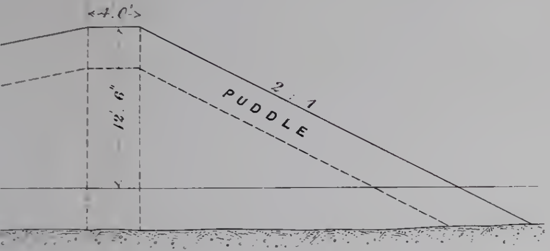
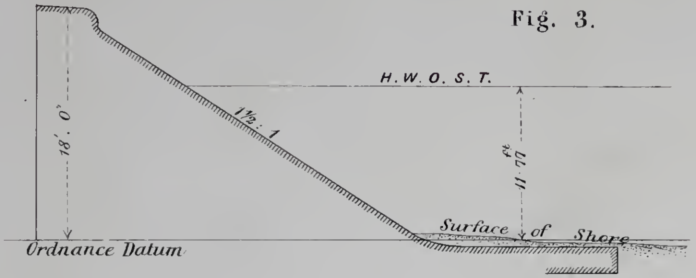
RY OF THE NENE.



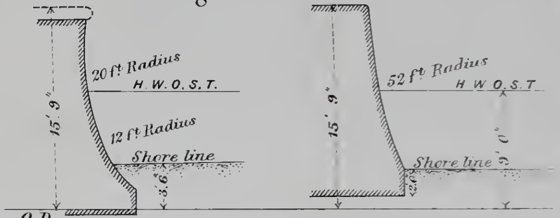
WALTON ON THE NAZE.

Fig. 3.



WESTGATE.

Fig. 4.



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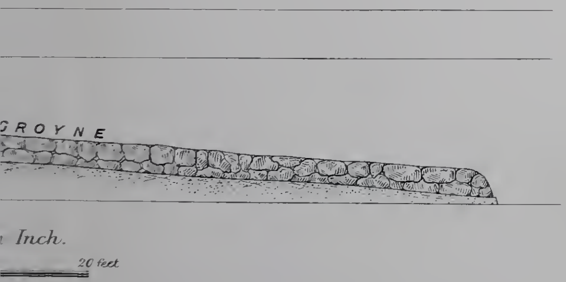
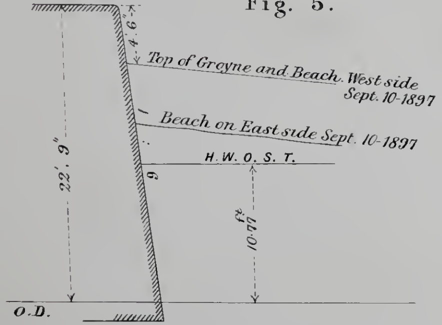


Inch.

HOVE SEA WALL.

Fig. 5.


4.6
Top of Groyne and Beach. West side Sept. 10-1897
Beach on East side Sept. 10-1897
H. W. O. S. T.
22'. 9"
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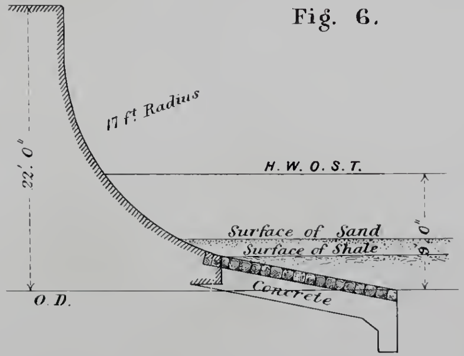
O.D.

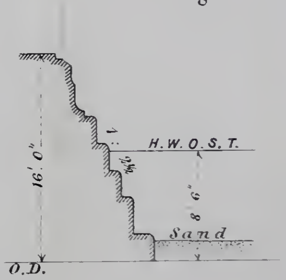
SCARBOROUGH.

Fig. 6.



MARGATE.

Fig. 7.



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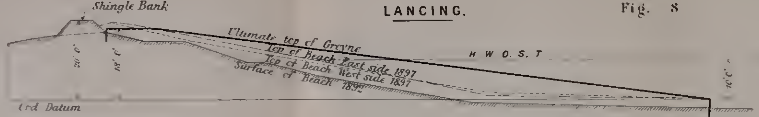
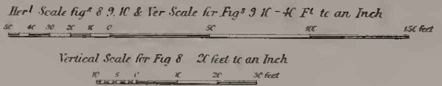
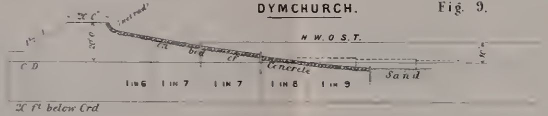
LANCING. Fig. 8




Hor^l Scale fig^s 8 .9. 10 & Ver Scale for Fig^s 9 10 – 40 F^t to an Inch
50 40 30 20 10 0 50 100 150 feet
Vertical Scale for Fig 8 20 feet to an Inch
10 5 0 10 20 30 feet

DYMCHURCH. Fig. 9.



NEW ROMNEY LEVEL. Fig. 10.

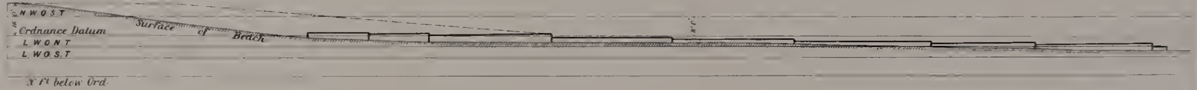
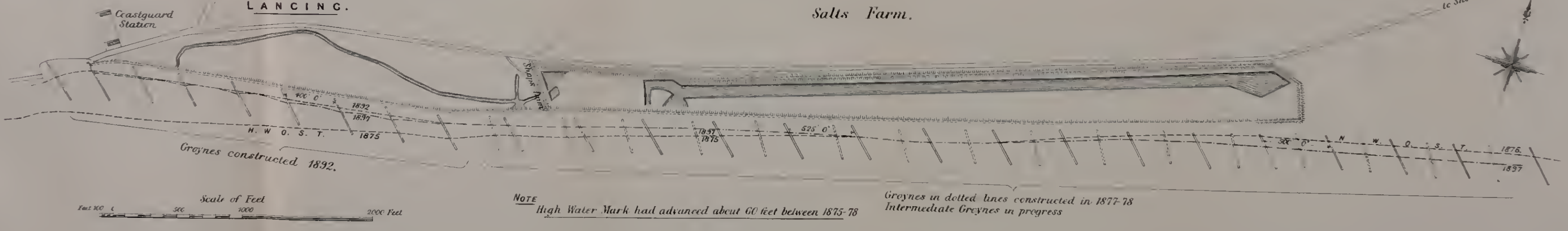


Fig. 11.

LANCING.



Note
High Water Mark had advanced about 60 feet between 1875-78

Groynes in dotted lines constructed in 1877-78
Intermediate Groynes in progress

E. & F N Spon L^td, London

December 6th, 1897.

GEORGE MAXWELL LAWFORD, PRESIDENT,
IN THE CHAIR.

THE POLLUTION OF WATER, AND ITS CORRECTION.*

BY REGINALD EMPSON MIDDLETON.

THE recent epidemics of typhoid fever at Maidstone and King's Lynn, which have spread ruin and desolation through these towns, have forced upon our notice, in an exceedingly unpleasant but most practical manner, the fact that, while water is one of the primary necessities of existence, it may become, unless carefully safeguarded, a subtle poison, carrying with it disease and death. From time immemorial running water has been used for two separate and antagonistic purposes, namely, as a source of water supply and as a receptacle for refuse, and so persistently have people put the 'cart before the horse, that, even in very recent years, it has been authoritatively stated that the first use of running water is to remove refuse.

It is necessary, under these circumstances, to lay great stress on what might otherwise be considered a truism, namely, that water is provided in the first place for dietetic and cleansing purposes, and that the removal of refuse must be subordinated to this first and most important requirement. As the water supply of Maidstone is, it is understood, to be subjected to a searching inquiry, it does not become us, at this stage, to prejudge the issue in any way, but there does not seem to be any doubt that in some manner or another a portion of the water supply became contaminated with the germs of typhoid fever, and that a most fearful and fatal epidemic has resulted, the notified cases of the disease having numbered some 1883, out of a population of 32,145, or 5·86 per cent., while the deaths numbered 142, or 7·54 per cent. of the reported cases. No doubt many of the cases are not directly attributable to the use of polluted water, but though they have resulted from secondary infection, the disease would not have been contracted if the water supply had been pure. At King's Lynn the number of cases recorded is 425, out of a population of 18,360, and the deaths number 43, or 2·31 and 10·1 per cent. respectively.

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* The Rawlinson Premium was awarded to the author for this paper.

It was assumed that the spring, or springs, from which a portion of the Maidstone supply was drawn had been polluted by hop-pickers suffering from typhoid fever, but doubts are now thrown on this explanation owing to the absence of any evidence that any hop-picknrs were suffering from the disease. It has been suggested in the *Public Health Engineer* that the health of the population living in the town had been reduced by the presence of sewer gas in large quantities, and that the water may have become contaminated by leakage from a sewer. However this may be, the fact remains that there has been a fearful and preventable loss of life and widespread distress, the end of which is not yet.

Statistics prove, in the clearest manner, that the first element of aggregated health is to be found in a pure and sufficient water supply, and we may congratulate ourselves that the Royal Commission of 1892–93, after an exhaustive inquiry, stated most emphatically that the water supplied to us is above suspicion, and the very low death rate of our vast metropolis fully confirms this statement.

Notwithstanding the fact that the purity of its water supply has a greater influence on the health of a town than the efficiency of its drainage system, legislature has insisted much more strongly on the necessity for the removal of refuse than on pure water, as is very clearly shown by the very tentative wording of the Rivers Pollution Act, 1876, which is so elastic that it has been next to impossible to enforce the purification of sewage matter in an efficient manner, unless the authorities themselves were anxious to deal with it. The discharge of sewage matter from house drains and sewers cannot be carried out in a proper manner unless water is provided for the carriage and propulsion of the sewage, yet many places have received an elaborate system of sewers long before any system of water supply was instituted. Those who remember the state of the Thames opposite the Houses of Parliament in the fifties, and the vile smell which emanated therefrom, may conclude that the Legislature was led by its collective nose, and that we may thank that evil-smelling river for providing us, in many cases, with sewers, before we had water wherewith to flush them.

When speaking of pure water it must be remembered that no water in nature is chemically pure. Rain, in passing through the atmosphere, collects impurities, which may or may not be injurious to health. When it reaches the ground or buildings it picks up other impurities, such as soot, road detritus, and the microscopic life which pervades both the atmosphere and everything we eat, drink, or handle—ourselves included; and so great may be the impurity of the surface on which the rain falls that the washings of a busy street are probably more highly polluted than the contents of a house drain.

Water which has passed over or through soil covered with vegetation contains some remnants of the vegetable matter it has touched, along with a new assortment of micro-organisms; that which has passed over or through beds of rock carries with it some portion of the mineral substance. On all sides we find change of condition; some impurities—and anything added to pure, distilled and sterilised water must be considered as an impurity, whether it be injurious or no—are removed, others added; thus the water which has percolated through clean soil and has reached the underground reservoir which exists at a greater or less depth below the surface in most if not all parts of the earth, is generally found to have parted with nearly all but its mineral impurities. Deep well water contains few micro-organisms, but it is frequently hard, that is to say, it is impregnated with lime, magnesia, or other substance collected on its way to the underground basin and thence to the sea.

The most natural conclusion to be arrived at from these remarks, is that if pure water is to be provided it must be obtained from deep wells or from uninhabited or sparsely inhabited districts; these are not, however, the conclusions which a full examination of the subject will confirm. Nature is always steadily and persistently endeavouring to undo the evil which man effects, and, given a fair opportunity and reasonable time, she will bring back the most polluted water to a condition of healthful purity. It is man's duty to assist her in her efforts, not to combat them.

Deep well water is generally free from micro-organisms, that is to say, it contains but few. If it were possible to deliver water to the consumer in this condition he could not ask for anything better; but, just because it contains but few organisms, it is exceedingly receptive of pollution. It is delivered to the consumer direct from the well, and there is no second or third line of defence against the transmission of disease as in the case of river water stored in reservoirs and filtered. That the pollution of deep wells is of rare occurrence is not an answer to this objection: failure in the delivery of pure water should be guarded against so far as human prescience will allow. The bacilli ordinarily present in water are not injurious to health; may we not go further and say that their presence implies that they are beneficial? Moreover, if pathogenic germs be introduced into water in which they, the ordinary organisms, exist, they are believed to rise in arms to destroy the intruders; but if they are in the minority, as they probably would be in deep well water, it is they who are destroyed, and the pathogenic germs who increase and multiply.

The chance of a number of pathogenic bacteria sufficient to cause disease in a receptive individual being introduced into the body, must be to a large extent relative to the volume; thus, if a pint of water contains a million germs, and the whole pint is imbibed by one person, the chance of his feeling the effects of his dose of bacilli depends on his receptivity; but if the same number of organisms are distributed over 100 million gallons, the diffusion is great, and the danger of any one person drinking a sufficient dose of the poison to produce disease is not great. Deep wells seldom yield more than 3 million gallons a day each, and generally considerably less; therefore, if the water containing few organisms become polluted, and is delivered unfiltered, its pollution is a serious matter. In the same manner, though not in the same degree, the incidental or casual pollution of a small stream is far more dangerous than in the case of a large river: the dilution in the latter case is much greater, there are fewer pathogenic organisms in the pint, and there are always a superabundance of the bacilli who war with the dangerous ones, to put the latter in a minority.

In the case of the casual pollution of a deep well, all the incoming water is pure, but contains few organisms to destroy the vitality of those which are dangerous to health. In a river the incoming water may or may not be pure, but there are other forces all tending towards purification, namely, sedimentation, vegetation, oxidisation and light, and the power of these must depend on the extent of the pollution, which may become so great as to destroy and nullify the forces tending to purification. Where water is collected from uninhabited districts, it is frequently found that another form of pollution is present and that a large quantity of vegetable matter, often of a peaty character, is delivered to the consumer, producing diarrhœa in those who are unaccustomed to its use, and rendering the water unpalatable. Some qualities of soft water affect lead pipes and produce lead poisoning where such pipes are employed for distribution, and to prevent this effect iron pipes, or pipes coated with tin, must be used.

It is true that most people prefer soft water for washing, although it is doubtful if its cleansing powers are so great as with a harder water; soft water is generally to be preferred for steam and manufacturing purposes, but after all the first consideration is health, and, although the quantity of water which is drunk may form but an infinitesimal part of the whole, it is this consideration, and this only, which should govern the selection of the supply. Those who use soft water habitually do not suffer from its use, but the same thing may be said about many people who live under insanitary conditions; they do not suffer, but the same conditions are fatal to a stranger, and it is undesirable to change conditions which have proved to be satisfactory, for others, which the experience of other cities has certainly not proved to be better.

It is quite impossible to deal with specific forms of pollution in the scope of a paper like this; it is necessary to consider them very generally. The great polluting element is man, whether considered as an individual, or as an aggregation of individuals, or as a manufacturer. The sewage of isolated houses is seldom very dangerous, the products are generally largely desiccated or otherwise destroyed before they find their way into the river; villages are more dangerous, all the more because they are seldom adequately dealt with; towns, though the greatest offenders, generally make some efforts, more or less adequate, to deal with their sewage before they discharge the effluent into the river; but that sewage disposal receives the attention which should be given to it cannot be affirmed.

Many towns are so situated that the acquisition of land suitable to be laid out in a system of broad irrigation is difficult or impossible. Where resort is had to intermittent filtration the ground must be thoroughly adapted for its purpose, and in either case provision should be made for dealing with a large excess of storm water—at a time of the year, moreover, when the ground is already supersaturated and the vegetation will not take up any more moisture. Saturated soil will not cleanse sewage, nor will vegetation which is already full of moisture deal with it, and under these conditions the effluent passes into the river practically unpurified. No chemical treatment of sewage is by itself, it is thought, sufficient to produce an effluent of satisfactory purity, and any such treatment must tend to arrest in a greater or less degree the purifying effect of the biological forces in nature.

It is believed that the cleansing effect of soil on sewage or polluted water is limited almost entirely to the upper few inches in depth, that the process becomes slower as the depth below the surface increases, and that it ceases, almost if not altogether completely, when the level of saturation is reached. It may be assumed therefore that aeration is a necessary part of the purifying process, and that water may be passed horizontally or nearly horizontally for an indefinite distance through soil and below the surface of the ground without the dangerous properties contained in it being removed from it. It follows therefore that the arguments against the efficacy of the downward filtration of water through sand, based on known cases of the transmission of disease through water-logged strata, fall to the ground.

Soil, in order that it may have its highest purifying effect, should be dry, and it is failure in complying with this condition which has defeated the many efforts which have been made to render the dry earth system general. The same cause leads to the pollution of many surface wells; the soil about them is loaded with moisture from slops, manure heaps, and farmyard refuse, until it loses its vivifying power and foul matter finds its way into them unpurified and unchecked. Leakage from a sewer or drain will produce the same effect, because, being below the surface of the ground, the sewage is practically unaffected by the soil it passes through, because the volume is in excess of that with which the soil can contend. The powers of nature are limited and cannot be overstrained, as most of us know to our cost. Soil, even the best of it—and much which is used for the purpose is far from being the best—can only deal effectually with a limited quantity of sewage, and if to the quantity be added a large volume of pure water, failure is the result.

As has already been pointed out, early legislation was directed rather to the removal of sewage than to the protection of the sources of water supply, and the Rivers Pollution Act, 1876, is so elastic as to be ineffectual in enforcing on authorities and individuals the duty of passing a safe and satisfactory effluent into rivers. The Mersey and Irwell Act, 1892, and the Thames Conservancy Acts, 1894, have been prepared with the object, *inter alia*, of giving increased powers to the authorities interested in dealing with pollutions, and similar powers should, it is thought, be in force throughout the country. Clauses 93 and 94 of the Thames Conservancy Acts, 1894, read as follows, and are sufficiently stringent.

"93.—If any person does any of the following things, namely:—

(1) Opens into the Thames, or into any tributary, any sewer, drain pipe or channel whereby sewage or any other offensive or injurious matter, whether solid or fluid, shall, or is likely to, flow or pass into the Thames or into such tributary;

(2) Wilfully causes, or without lawful excuse (the proof whereof shall be upon him) suffers any sewage or matter aforesaid to flow or pass into the Thames, or into any tributary, down or through any sewer, drain pipe or channel, not at the passing of this Act lawfully used for that purpose;

He shall, for every such offence, be liable to a penalty not exceeding fifty pounds.

94.—(1) Whenever any sewage or matter aforesaid is caused or suffered to flow or pass into the Thames, or into any tributary, then, and in every such case, even though such sewage or matter aforesaid had been lawfully so caused or suffered to flow or pass before the passing of this Act, the Conservators shall give notice in writing to the person causing or suffering the same so to flow or pass, requiring him within a time to be specified in such notice, but not being less than three months, to discontinue such flow or passage.

(2) Provided that the Conservators may, if they think fit, at any time, and from time to time, extend the time specified in such notice by another notice in writing.

(3) And provided that if any person, to whom any such notice is given, thinks himself aggrieved by reason of the time allowed, either by the original or by any subsequent notice, not being sufficient, he may, not later than one month before the expiration of the time so allowed, by writing delivered to the Secretary, demand an extension of such time, and in case the Conservators refuse to comply with such demand, the question of such extension shall be referred to an arbitrator appointed by agreement, or failing agreement, by the Board of Trade, on the application of either party.

(4) Any person to whom any notice is under this section given by the Conservators shall, notwithstanding anything in any other Act, within the time allowed by such notice, subject to any extension of such time as in this section provided, discontinue the flow or passage of the sewage or matter to which the notice refers, and in default of so doing shall be guilty of a misdemeanor, and be liable on summary conviction thereof, or on conviction thereof on indictment, to a penalty not exceeding one hundred pounds, and to a daily penalty not exceeding fifty pounds.

(5) Provided that, notwithstanding anything in this Act, or in any Act incorporated therewith, any proceeding in respect of such a misdemeanor may be removed by *Certiorari* into the High Court."

The Bradford Improvements Act of 1897 prohibits the passing of untreated trade refuse into sewers under a heavy penalty.

Stress has frequently been laid on the danger of using water which has run off highly manured land. It is thought that this danger has been somewhat exaggerated, for the quantity of water which runs over and off the land without percolating is, generally speaking, small. That which percolates passes through a process of purification, while the surface water running off pasture land is subjected to the action of vegetation, and is also purified to a greater or lesser extent, according to circumstances.

The writer believes that, as he stated in a paper communicated to the Congress of Hygiene, held in Buda-Pest in 1894, the solution of the difficulty in dealing with the disposal of sewage is to be found in sand or similar filtration, probably accompanied by some method of breaking up the solids by biological treatment. A system of this character offers immense advantages in the disposal of the sewage of large towns, which might be broken up into sections of, say, 5000 inhabitants, each with its separate disposal works, the effluent from which might be turned into the nearest natural watercourse. The filters might be laid out under squares in open places, out of sight, and if properly ventilated—a necessary part of the scheme, both for the sake of rapidity in treatment and for freedom from effluvia—out of mind also so far as the general public is concerned. Such an arrangement obviates the necessity for any but small sewers, and all the gigantic apparatus of trunk sewerage, along with its enormous cost and complications, could be dispensed with.

The author does not pretend that a system such as he has described can be adopted right off the reel, but he believes that inquiry is tending in this direction, and that the time is not far distant when it will be accepted both as the natural, following as it does the dictates of nature, but also the simplest solution of this most difficult problem. When this time arrives there will be hope for our rivers, for it cannot be any longer pleaded that suitable land or a satisfactory site cannot be procured, and the quality of the effluents will depend solely on the area of filtration and the care taken in working the filters.

One consideration, however, militates greatly against the speedy introduction of such a system, namely, that if it is to be efficient it must be worked as a scientific machine with the same care and attention as is devoted to the working of the filter of a great water supply, and this desideratum cannot be secured in the cases of village sewerage works; many such sewage disposal works might never have been constructed for all the good they are. Sewage tanks cracked and leaking, where the sewage flows in and flows out again in the same condition, full of putrid and evil-smelling matter, filtration areas so sodden that the sewage will not sink through the ground, so-called filters which do nothing more than remove the heavier solids, and farms where the sewage is only passed over the land when it happens to suit the convenience of the farmer, and at other times lies in pools or flows away untreated, are common.

It is a matter of history that sources of supply, which appeared to be absolutely free from all danger of pollution, have been polluted, that even deep wells have not been entirely free from danger, and as these sources of supply are not provided with any second line of defence, if they do go wrong, the results are disastrous indeed. The first line of defence should be the protection of all water from deliberate pollution; the second is found in sedimentation, and the third in efficient sand filtration.

That sand filtration is a good and sufficient defence against the danger of the transmission of pathogenic germs to the consumer is very clearly stated in Dr. Percy Frankland's paper, read before the Sanitary Congress at Newcastle-on-Tyne in 1896. Dr. Frankland instances the case of Altona, and gives the results of the working of ten filter beds attached to the waterworks of that town during eighteen days of the month of February, 1893. The raw river water drawn from the river Elbe, which received the untreated sewage of more than four millions of persons, along with the more or less treated sewage of a further population of a million and three-quarters, contained on an average 28,667 bacteria per cubic centimetre, while the average number present in the filtered water was 90 per cubic centimetre, representing an average reduction of 99·69 per cent.

The discoveries of late years in the direction of bacteriological research have been so startling that there has been a tendency to magnify the use of biological investigation into the purity of water supplies at the expense of chemical examination. This is much to be deprecated; bacteriological tests are useful as adjuncts to an examination under the microscope and by chemical means, but alone they tell nothing of the history of the water, no more than that there are a certain number of bacteria, harmless or otherwise, at a particular moment. Carried further it may prove the presence or absence of pathogenic bacteria, but it says nothing of the why of their presence or absence. Moreover, the presence of large numbers of bacteria in a sample of water may be conjectured to show that there is something in it on which they feed which would not be found in quite pure water, but the something may be quite harmless nevertheless.

Storage of water has a remarkable effect in reducing the number of bacteria contained in the raw material. In the Registrar General's Reports for 1896 there is some very instructive reading on this subject and on the effects produced by filtration, thus:—

After 4 days' storage the average number of bacteria in the raw river water was reduced by	58 per cent.
After 5·3 days' storage by	68 „
„ 5·6 „ „	80 „
„ 12 „ „	98 „
„ 17 „ „	83 „
„ 28 „ „	96 „

Considering that the observations have reference to different storage systems, the actual time of storage varying with the time of year, and being something less than that quoted, and that the raw water is drawn from different rivers, the results obtained are remarkably consecutive, and serve to show what a wonderfully strong second line of defence may be provided by efficient storage, the third line being found in the filter, which removes from 98 per cent. to 99 per cent. of the bacteria remaining in the water. In this manner, in the water of the Thames, containing some 24,107 microbes per cubic centimetre, after 12 days' storage only, no more than 508 bacteria per cubic centimetre were found, and after subsequent filtration only 34 microbes per cubic centimetre, or a reduction of 99·86 per cent.

The figures given above are averaged, and like all similar figures, must be accepted with a certain amount of reserve, but where it is found that the very worst results obtained record a removal of 77·14 per cent., the average minimum being 88·84 per cent., and the general average 99·60 per cent., it may be concluded that any departure from actual truth is very trifling, and that the protection afforded is eminently satisfactory.

Because, however, a system of storage reservoirs, combined with efficient and carefully conducted sand filtration (filtration which is not carefully conducted may be very inefficient indeed) forms a strong defence against the introduction of disease through water supplies, the necessity for the protection of water against anything but the most accidental and fortuitous pollution must not be lost sight of; streams and rivers need not, and ought not to be polluted, and all authorities should be compelled to do their duty in this respect.

To this end it seems desirable that for water supply and sanitary purposes, drainage areas of streams and rivers should be under the authority of boards or councils, whose duty it should be to provide for the conservation of the water, and who should rigidly enforce the law against pollution.

DISCUSSION.

The PRESIDENT said that, in asking the meeting to accord a hearty vote of thanks to Mr. Middleton, he did so with the knowledge that the paper had been thoroughly appreciated. Mr. Middleton was no stranger to the Society, and in fact only two years ago he was awarded for a paper the gold medal of the Society, which was the highest honour they had to bestow.

The vote of thanks was passed with acclamation.

Mr. W. WHITAKER, F.R.S., said that he rather objected to the application of the word "impurities" to mineral matters in the water. Such matters were, to some extent, rather good than bad, though, no doubt, some waters contained over much mineral matter, which could not be easily accounted for. He had lately had before him the analysis of a deep well water, presumed to come up from over 800 feet, and the main solid ingredient of which seemed to be carbonate of soda. That water was not allowed to be used for public purposes, but it was used for brewing, and it was said that it made uncommonly good porter. If it was not for the persistent efforts of nature to purify water, society would be in a very bad way. The weakness of well water for absorbing bacteria was a very curious thing. Deep chalk waters seemed to grow all sorts of things if they were left open to the light and air: aeration did them harm, although to surface water it did the reverse. This fact showed the necessity of taking into account the origin of the water which was to be dealt with. He was inclined to agree with the author on the subject of soft water: after using it for washing he felt as if he had not thoroughly washed. It was, no doubt, the case that persons who were accustomed to use hard water were upset by the use of soft, and *vice versâ*. The human body had a habit of focussing itself to its surroundings. Perhaps this habit of the body was not a good thing in the case of persons who were living in insanitary areas.

The public were much in the dark with regard to the cause of the pollution of the Maidstone water, but there was to be a public inquiry, and until that was held very little could be said on the subject. It had been stated that the chalk springs which supplied Maidstone had been contaminated, but as a matter of fact they had not been touched. It was very lucky for Maidstone that it had a triple supply of water, namely, from chalk springs, from a well into Lower Greensand, and from Lower Greensand springs. If all the water had been supplied from one source the results might have been far worse. In addition a neighbouring company gave a temporary supply of excellent water. He knew something with regard to the case of Lynn, as he had lived there, and he could state that the fault of the polluted supply at that place lay with the inhabitants themselves, through obstinate ignorance. They had been warned by different people for years, but they had paid very little attention to the warning. The corporation and the officials had been perfectly ready to bring a good supply of water into the town, but the absolute objection of the population to do anything which would promote their health had led to the epidemic. Probably the people who had suffered were not the wrongdoers; if they were, less pity would be felt. It seemed a dreadful thing that a majority of the inhabitants of a town should have the power of victimising the minority simply to save their wretched rates. In the end the rates were not saved; on the contrary the expenses were increased, because the necessary work had to be done in a hurry. He was not inclined to go with Mr. Middleton when he said that well-supplies were not, on the whole, so good as supplies drawn from the surface, or from rivers. He regarded supplies from various sources as good, provided they were properly treated. If there was a river supply there ought to be a conservancy board with strong powers and a strong will to use them. As to London, the Thames Conservancy had been given further powers of late years, and they had used them, but he was inclined to think that they wanted still larger powers. It was not fair to the water-companies that they should not be fully protected by the board to whom they must look for their supply. Every effort should be made to keep out all noxious matters not only from the principal river, but also from its tributaries. There had been a great advance of late years in this respect. Some of the London companies had spent a large amount of money in trying to get well-water to supplement their other supply, and it should be remembered that one of them got its water wholly from wells. He was afraid they would not succeed in getting the whole supply from wells. Mr. Middleton was, in his opinion, right in proposing to take the watershed-area as the unit which should be dealt with. The watershed ought not to be split up into different parts, tributaries being dealt with separately. That state of things did not yet exist in the case of the Thames, but until it was reached the water supply of London would not be thoroughly satisfactory. In the north of England and in manufacturing districts a totally different state of things was met with. He felt horrified at first by what he saw at Leeds a little while ago. Sewage was treated with lime, run into tanks for a few hours, and allowed to subside in passing through a huge tank with various partitions, and run out again. The effluent, was, to say the least, a muddy water, but the river into which it ran was perhaps worse than the effluent, so that it had been said that the effluent was really diluting the river. Such a state of things would not be allowed in the south of England. That showed that they must consider each case and the circumstances which surrounded it.

He should like to hear the opinion of engineers upon the proposal of the author to split up large towns into small ones with about five thousand inhabitants as the unit. In order to apply that system to London many hundred different sewage schemes would have to be carried out, the inhabitants would be walking over sewage schemes all day, and they would soon get to know it. If they did not smell a nuisance they would fancy that they did, and that would be very much the same thing. Round waterworks there ought to be a certain area where the water-bearing beds would be protected from assault; but as to what the extent and form of that area should be nothing could be said at present. That would be a matter for investigation. In the case of Maidstone the pollution was supposed to have come from the immediate neighbourhood of the spring, the source of which was the Kentish Rag. Engineers must in future think not only of saving the area from which they brought their water from being overdrawn on, but also of the protection of the supply from pollution. Perhaps schemes should contain a clause prohibiting the existence of a nuisance within a certain distance of the supply. He felt certain that that would be provided for by the promoters of schemes in the far distant future.

Mr. A. M. Fowler said that the paper was very carefully prepared and exceedingly interesting. The keynote which they ought to strike was that of more strict supervision by the legislature. The officers of health of every town ought to have power to superintend and take the supervision of the source of supply. There were many places which were supposed to afford an unpolluted supply of water partly from cultivated land, and which were visited during holiday times by large numbers of picnic parties, so that they would be very likely to be to a certain extent polluted. He was rather surprised to hear the last speaker object to soft water. Some of the best engineers and chemists had said that if London possessed a supply of water which was below five degrees of hardness, enough money would be saved in one year to pay for an efficient water supply from Wales. Statistics had shown that the poor man could wash his shirt more frequently in soft water than in hard. The amount of chloride of lime and of soda which had to be used for washing in hard water was so great that linen and cotton fabrics were destroyed in a very few washings. In other words, fabrics would last four or five times as long if they were washed in soft water as if they were washed in hard. It was once thought that hard water towns were more healthy than soft water towns, but statistics showed that there was very little difference in the death rate between the two cases. Hard water made better beer than soft; but soft water effected a saving in tea and many other things, and therefore a soft water supply was to be preferred. He granted that soft water ought to be free from peat and from surface contamination. It was a peculiarity of peat that it could never be filtered out, but it could be bleached to a large extent. All waters, or at all events all surface waters, ought to be filtered. The filters which he had seen lately at Dorking and in Hungary were a very great improvement upon the old fashioned filters. They could be cleansed almost immediately by a reversal of the current of water, and germs of contagion could be detected in a very simple way, whereas the cleansing of sand filters entailed very great labour. The effluent at Leeds sewage works had been a little exaggerated. He designed and carried out those works twenty-five years ago, but they were now too heavily taxed with work, and were not a quarter of the size that they ought to be for the present population. The last time he visited them one of the party present was so pleased with the effluent that he drank a glass of it. At Leeds there was no land available, and the sewage had to be treated by the lime process, and there was not tank room to allow of sufficient subsidence. He thought the Leeds effluent was remarkably good considering the circumstances under which it had to be produced. He protested against the flippant style in which it had been spoken of by the last speaker.

Mr. B. Blount said that Mr. Middleton had been a little hard on deep wells. He seemed to think that a water which was originally very pure had a greater chance of becoming impure than a water which was originally impure. The doctrine that a host of benevolent germs arose and slaughtered those that were mischievous was a very comfortable one, but he thought that most engineers would prefer for their own consumption a draught of deep well water to water drawn from an ordinary river supply. He was in entire agreement with Mr. Middleton in thinking that hard water was, on the whole, better than soft for drinking and domestic use. Probably the mania for soft water arose from a misuse of statistics. Persons possessing a small chemical knowledge had calculated how much soap was necessary to soften a gallon of water entirely, and then, by calculating how many gallons of water were used in certain operations had arrived at a stupendous consumption of soap. But when a man washed his hands in a basin of water he did not soften the whole of the water in the basin by means of the soap he was using. He merely softened the small amount of water which adhered to the surface of his hands. He thought that no candid person who had had experience of the use of the two classes of water could have any doubt as to which was to be preferred. After washing in hard water one felt clean and free from that objectionable greasy feeling commonly experienced after using soft water; for this sound chemical reasons existed.

He agreed with what Mr. Middleton had said with regard to the stringent powers conferred on the Thames Conservancy; and no doubt those powers were on the whole used with great wisdom and effect; but occasionally hardship arose. In a case in which he had been recently asked to advise, an effluent was being poured into the Brent, which although not unexceptionable, was of much better quality than the water of the Brent itself, nevertheless the Thames Conservators wished to stop its influx. He agreed with the author in the idea that, on the whole, a chemical examination of a water gave a better indication of its quality than a merely bacteriological examination. The latter did not give the history of a water in the same way that a chemical examination would give it, and it did not show whether the organisms found in the water were normal inhabitants or merely adventitious. The guarding of the purity of many of the water supplies of the country must ultimately depend upon a chemical examination of the water. But he must give one word of praise to the bacteriological examination of water in checking the action of the sand filters. Such filters proved most efficacious when they were properly managed as they were in the case of large and well ordered water companies, such as those which supplied the metropolis; and a bacteriological examination of the water was, perhaps, about the best and easiest way of judging whether a sand filter was really acting up to its work. It showed the action of a filter *qua* filter as distinct from gauging the degree of purification of the water.

Dr. J. C. THRESH said, that whilst the serious outbreaks of typhoid fever at Maidstone and at Lynn emphasised the importance of the present subject, they need not cause any serious alarm. Had they occurred in towns in which the utmost care had been taken to protect the water supplies there might have been some cause for panic, but he knew from his own personal observation that such was not the case. Such epidemics were preventable and the only serious questions were, Why were they not prevented in those particular instances? and, Were there any other localities which were running the same risk? He would not answer the first question, but as to the second he was bound to say that there were localities which were using water which was equally liable to pollution. The author had done good service in showing how, in certain cases, such risks might be reduced, but many statements contained in the paper were doubtless open to criticism. Deep well water had been spoken of disparagingly because it was so pure and contained so few organisms. That objection was an extraordinary one, and if followed to its logical conclusion would be found to be absurd. The pollution of deep well water was preventable, and it was the duty of those who provided it to supply it in a state of purity. It was unreasonable to object to it because nature had filtered it so perfectly.

The next statement to which he (Dr. Thresh) took exception was that water might be passed horizontally or nearly horizontally for an indefinite distance through soil or through ground without its dangerous properties being removed. That was a pure assumption, and his own investigations enabled him to assert that the subsoil had a wonderfully purifying effect upon water. In a case which he had had to investigate he found that the water of a well, which was within 10 feet of a dead well used as a receptacle for sewage, was organically very pure. The ten feet of soil between the two wells had been sufficient to purify the water which drained from the dead well into the other, and that state of things had existed for half a century. In another case there were two dead wells receiving sewage within 30 feet of a well yielding a public water supply, but, nevertheless, he was unable to detect in the water any evidence, either bacteriological or chemical, which would give rise to the suspicion that there was any source of pollution so near. It was a remarkable fact that subsoil water was very free from organisms. In order to obtain a safe subsoil supply, all that was necessary was to secure a proper situation for the well with a properly protected area of sufficient extent around it, under the absolute control of the purveyors of the water. He believed that the bacteriological purification of sewage for preventing the pollution of rivers would soon become practicable on a large scale. The effects which could be obtained from coke filters were remarkable. The success of such an inexpensive process as that of filtering by means of coke ought to remove the last shred of excuse for casting sewage into rivers. Very few county councils made use of the powers which they possessed with regard to that matter. If they were sufficiently alive to their responsibilities they would take in hand the superintendence of the water supplies and the drainage areas within their districts.

Mr. PERCY GRIFFITH said that he approached the subject from the point of view of water supply and not from the point of view of drainage. It was rather difficult to judge from the paper which side of the question the author had principally in his mind, but apparently he had both. The author made a great point that the conservation and protection of water supply should precede works of drainage, and he was disposed to support the author very strongly in that view. He would go even further and say that in nine cases out of ten, particularly in small towns and rural districts, if a proper water supply was provided free from the least risk of contamination, a public system of drainage would be unnecessary. It would be evident that in hundreds of villages and rural districts which were now without either drainage or water supply, the latter could be carried out on a very much more satisfactory financial basis than the former. Long lengths of sewers or drains were a serious matter to deal with in rural districts where the houses were very widely distributed. Besides that, a water supply would bring in a revenue, whereas drainage works would not. Again, drainage works would require a considerable area of land, and that could not be obtained compulsorily without an Act of Parliament. Another point affecting the financial question was that in rural districts a large portion of the area which was subject to rating was agricultural land which did not derive any benefit from the sewage works, and consequently the question of cost was a very serious consideration. If a water supply could be carried out in all small towns and rural districts, the pollution of rivers and of subsoil water by drainage would be a comparatively unimportant matter.

It was very seldom that disease was propagated in consequence of the insanitary condition of a drainage system *per se*, and, in fact, he had never heard of such a case. Let the water supply of a place be isolated and secured against any possible contamination, and the bugbear of a large and expensive scheme of drainage would be unnecessary. He thought that the author was not justified in casting a slur upon deep well water. The author had shown that if surface waters were to be used for water supply, it was necessary to protect them. Then surely it could not be said that it was better to protect surface waters and use them than to make use of deep well waters which needed no protection. The statement that pure water from deep wells was more liable to bacteriological contamination than the less pure water of the surface could hardly be used as an argument in favour of the less pure water. It was the duty of the engineer who obtained a pure supply from a deep well to guard it against contamination in its passage to the consumer. The assistance which nature gave in purifying a surface supply was not an argument for giving such a supply the preference. The author had asserted that hardness had been proved to be a security against contamination; and it must be remembered that hardness was a characteristic of deep well waters rather than of subsoil and surface waters.

Another point to be considered was expense; and surely the author was aware that the expense of dealing with surface and subsoil waters was enormously in excess of the cost of dealing with deep well waters. The compensation which had to be paid to riparian owners by companies or local authorities which were acquiring water rights for the supply of surface water was enormous, and made it almost impossible for a small scheme to be carried out for taking the supply from any visible source; but water could be taken from underground without any liability to pay compensation. Therefore, even on the score of expense, a deep well supply, if obtainable, was to be preferred. The expense of protecting surface water against contamination was another argument in the same direction. The conclusions to which the author had come, and the advice which the paper contained would be immensely useful in cases in which deep well water could not be obtained, but such cases were the exception rather than the rule.

The conclusions of the author with regard to bacteriology and filtration were, he took it, supported by most engineers of the present day; and the three lines of defence against a pollution of the water supply which the author had advocated, namely the protection of the source, storage for the purpose of aeration and settlement, and filtration, were most excellent for large towns such as London. If, however, the author meant to apply them to small towns, he (Mr. Griffith) would suggest that the adoption of all three would generally be impossible on account of the expense. He supported the author's suggestion in favour of the decentralisation of sewage works or the dividing up of a scheme of sewerage into distinct sections. He believed that it was the only possible solution of the difficulty of carrying out sewage works in rural districts where the houses stood in small isolated groups; but it would be first of all essential that the water supply should be isolated from any possible contamination: which done, it would probably be found that the drainage works might be of a comparatively simple character.

Dr. S. Rideal said that the paper was a very good *résumé* of all the arguments in favour of a river water supply, but he thought the author had gone rather out of his way to cast a slur upon deep well water. His argument on that subject seemed to be rather far fetched, inasmuch as the organisms which grew most rapidly in well water soon exhausted themselves, and it seemed to be more or less a question of food supply; also it would be strange if a water company having a deep well supply did not take every reasonable precaution to keep out pathogenic organisms from polluting the water. In the bacteriological examination of water, he, for one, did not believe that the number of organisms per cubic centimetre was any real criterion of the value of the water. The question was whether the water contained pathogenic organisms or not, and even when the number of organisms was in agreement with Koch's limit, that would be no evidence that they could not produce an epidemic. The number of organisms per cubic centimetre capable of growing at blood heat gave a much better criterion, and corresponded very fairly with the value of the water; but even then the number of organisms obtained on an agar plate was no indication of the actual number of pathogenic organisms present. If to the three lines of defence Mr. Middleton added a fourth, viz. boiling, or sterilising by passing through a Pasteur-Chamberland filter all the river water used for drinking purposes, then he would be inclined to admit such a river supply as satisfactory.

Mr. E. J. SILCOCK said that unfortunately the epidemic of typhoid fever at Lynn had exceeded the figures given in the paper. There had been up to the present time about 428 notified cases and forty-three deaths, but the epidemic was now practically over. The town of Lynn was situated on the edge of an alluvial plain known as the valley of the Fens. The village of Gaywood, which adjoined Lynn, practically formed part of the borough. The borough of Lynn and the village of Gaywood were supplied with water which was taken from a small stream known as the Gaywood River, and which took its rise from the springs in the chalk about seven miles due east of Lynn. That stream was unfortunately very small, and in that respect supported the statement of the author that a small stream was a dangerous source of supply. One of the main springs was almost under a farmyard, and the river was polluted almost from its source. Another of the springs was under a churchyard, and there was every opportunity for the drainage of the churchyard to get into the spring. The other springs were connected with various sources of pollution. The river took the whole drainage of a highly cultivated valley containing about two thousand inhabitants. The water supply of Lynn was taken from the stream within the borough. The water first passed into a small settling pond and then into small tanks, which were dignified with the name of filters. Practically there was neither sedimentation, storage, nor filtration. The so-called filter beds were about 200 square yards in area, and about a million gallons of water passed through them daily.

An epidemic of typhoid broke out at Lynn about five years ago, and it was traced to the water supply. On the instructions of the council he reported on the matter, and designed a new means of supply for which an Act of Parliament would have been necessary. But inasmuch as the corporation could not obtain the necessary authority from the ratepayers to promote a bill in Parliament that scheme could not be carried out. There was a majority of about five to one against the bill being promoted, and therefore other measures had to be adopted. Works were being carried out under a provisional order granted by the Local Government Board, and were within a few months of their completion. The probability was that if the inhabitants had not opposed the original scheme the works would have been completed a year ago, and the present epidemic of typhoid fever would not have occurred. The case of Lynn taught the danger of taking a water supply from a small stream, for in such a case the degree of dilution was bound to be small. In the vicinity of Gaywood a case of typhoid fever was notified on the 30th September. That was about ten days after the illness began. The excreta from the patient were distributed on the gardens which sloped towards the river. On the 29th September a rainfall of $2\frac{1}{4}$ inches in two or three hours occurred. The result was a big flood, and the stream from which the water supply was derived came down in a very turbid state, and after the proper period of incubation the epidemic broke out. Thus there was very strong circumstantial evidence that the stream was the cause of it. With regard to storage he looked upon it as even more important than filtration. If there had been a reservoir when the thunderstorm occurred, and ten or fourteen days' supply had been in hand, the intake could have been closed down, and the flood water could have been allowed to pass away, and it would have been highly improbable in that case that the epidemic would have appeared.

Mr. Perry F. Nursey said he was very glad that Mr. Silcock was present, because he had placed before the meeting the condition of the King's Lynn water supply in very clear and forcible terms. He (Mr. Nursey) had made himself acquainted with the question, and he was about to make a statement on the subject on very similar lines to those followed by Mr. Silcock, who had anticipated him, and had spoken from personal experience. The strictures which Mr. Whitaker had passed upon the inhabitants of King's Lynn were in no way too severe. In fact, the conduct of the ratepayers who opposed the original scheme was so reprehensible that it demanded much stronger terms than had been employed. He thought that the municipal authorities were not wholly blameless in the matter, for with the exception of one or two far-seeing men they opposed that scheme in the first place, and thus led the ratepayers to object to it, so that the town council were ultimately hoist with their own petard. However, as Mr. Silcock had explained, they had found a way out of their difficulty without going to Parliament, but the ratepayers, in revenge, had turned out of the council Mr. Thomas Brown, one of its most prominent members and the man who had saved the town from a far worse visitation than it was experiencing.

Mr. CHARLES E. CASSAL said that, at first sight, it might be supposed that Mr. Middleton had been bitten by some bacteriologist, and that a certain amount of the poison had been absorbed into his blood. However, that was not really so, and the very worst bacillus which bacteriologists had hitherto produced namely, the *bacteriologisticus rabidus*, had not in reality injured Mr. Middleton, although it might be supposed that he had stated in effect that a pure deep-well water was actually very dangerous for drinking, because it contained but few so-called beneficent organisms, and was therefore the more capable of affording a free field for the evil organisms which were concerned in the production of disease. Such a contention would be a development of a suggestion generally attributed to Dr. Dupré. He (Mr. Cassal) believed that Dr. Dupré, aided and abetted by Mr. Dibdin, the late chemist to the London County Council, first made the suggestion that it was advisable to train up bacteria in the way they should go in order that they might ultimately act as policemen or dragoons, to bring about the extinction of the evil-minded bacteria which were associated with disease. That was a very dangerous proposition.

An important bacteriological theory was that under certain conditions, so-called harmless organisms might become pathogenic. Not long ago it was stated—he believed by Sir Charles Cameron—at a congress at Edinburgh, that an organism generally regarded as harmless, could be led into temptation, and having fed upon sewage, became capable of producing typhoid fever. Bacteriology was not sufficiently advanced to be able to say definitely whether that could take place or not. The dangers of bacteriology were at present particularly threatening, and the claim of certain bacteriologists that by existing bacteriological processes, the question as to whether a water would produce disease could be decided, was a most dangerous and illegitimate claim. He would challenge all the bacteriologists who had ever bacteriologised, to prove that in any single instance a water which had been shown upon indisputable evidence to have produced disease had, upon a bacteriological test, yielded a micro-organism to which the production of that particular disease could be, without question, attributed. It would be seen that all the chances were against the detection of specific micro-organisms, when the nature of the processes which had to be employed were considered. There was no instance, and no likelihood, of the presence in water of the micro-organisms which were associated with the production of disease without their being accompanied with more than enough concomitant organic filth to be detected by the most ordinary chemical processes. And there was no evidence to show that if a person swallowed one or two of the organisms which were credited with the capacity of producing typhoid fever, he would be injured by them. Not only in reference to bacteriological fallacies, but in reference to purely chemical questions, he had often thought that in matters relating to water inquiries it would be very important that engineers and chemists should understand one another better. Many excellent Bills before Parliament had been lost through those two classes of experts not understanding one another's positions. It would serve a good purpose if the representative societies of chemists and the representative societies of engineers were to arrive at some understanding and *modus vivendi* on the subject of water supply.

He was in cordial agreement with Mr. Middleton in reference to many things that he had said, and he was disposed to believe that, at any rate from an abstract scientific point of view, Mr. Middleton had hit upon what might be in the future a solution of the great sewage problem. The bacterium might in this way, perhaps, be made beneficent and might be of considerable value. For that reason alone Mr. Middleton's paper ought to take high rank among the papers read before the Society. He sincerely trusted, however, that engineers would not be led any further along the dangerous roads of bacteriology. They must remember that bacteriology was only an aid to the chemical analysis of water, and was not a substitute for it.

As to the recent epidemics of typhoid, one could not, unfortunately, avoid the conclusions that the towns of Maidstone and King's Lynn could have expected nothing but what they had got. The idiotic system whereby the question as to whether or not precautions should be taken against outbreaks of disease was submitted to the greatest ignorance of the greatest number, must necessarily result, sooner or later, in such events as had taken place in those towns. Questions of such importance ought to be determined by some higher and more intelligent power than that exercised by the ignorant persons who constituted the majority of the ratepayers in the various towns throughout the country, but it was a fact which was sometimes lost sight of, that whatever steps were taken to safeguard a water supply, scientifically absolute safety was unknown, and unknowable.

Dr. Thresh appeared to have taken exception to the statement that water carrying polluting matters might pass through the soil without those matters being removed, and to have remarked that this was a pure assumption. Dr. Thresh observed that the subsoil could exert "a wonderfully purifying effect upon water." That was no doubt true with respect to certain subsoils, when they were clean, but the truth of the statement to which Dr. Thresh took exception was not affected by the fact, nor could it be contended that that statement was "a pure assumption." That there had been a great number of cases in which sources of water supply had been fouled by the percolation of polluting matters through soil was a perfectly well-known fact, and Dr. Thresh would not say that that was not so. But his remarks, if left unexplained, might bear that interpretation. The case cited by him afforded no evidence to justify the conclusion which he appeared to have drawn from it; and to assume on the facts stated that the ten feet of soil had been effecting a purifying process for half a century, or for any period, was obviously not permissible.

Colonel A. S. Jones, V.C., said he agreed with the whole of the paper with one or two exceptions, and with a great deal that had been said by many of the speakers. He was very glad that the author had not been carried away so much as some enthusiastic believers in bacteriology, and that he had stood up for the benevolent bacteria. He (Colonel Jones) believed that benevolent bacteria predominated all over the world, and that if they only had a fair chance they would destroy any typhoid bacteria that came upon a sewage farm. All attempts to purify sewage must be carried out carefully and scientifically, and a sewage farm must be dealt with as a delicate piece of machinery. He failed to find that any sewage farm had been treated in that way. If such places received the justice which was claimed by Mr. Dibdin and Mr. Cameron for their contrivances they would have had much greater success. As to sewage farms, and the proposal that a sewage scheme should be divided into sections, he should have agreed entirely with the author if he had proposed that a section should serve about 20,000 or 30,000 of the population instead of only 5000. He did not approve of the suggestion that the purification area should be placed underground. Light was one of the most important things in the process; and besides that, if the system was out of sight it would be out of mind. Everything connected with the sewage ought to be *coram populo* and absolutely known to the public. To let the system go into a hole and corner would be absolute blue ruin. It was the ruin of the whole business to look upon scavengering as low degrading work. A scavenger ought to be regarded as a most honourable man, and he ought to be encouraged to take an interest in his trade, and to carry it out intelligently like an artisan who had the superintendence of a delicate machine.

Mr. S. Newlyn, speaking as the secretary and manager of the waterworks of a district which had both deep well and river water as sources of supply, said the question of whether deep well water was good or otherwise depended upon the geological formation of the area. In his district they had carefully constructed wells with bores going down a considerable depth, and iron cylinders reaching to the clay formation; but the water could not be depended upon. It might be good one day and bad the next. They therefore took the river water, which, after treatment at the works, became one of the best waters supplied to the public, as proved by various analysts.

The managers of waterworks looked to engineers to devise the best plant for the purpose, and to chemists not only to show them what impurities water contained, but how best to remove those impurities. Local authorities on rivers above sources of supply were allowed to discharge sewage into the streams, and at present there was great difficulty in preventing them. Different legislation was required on that matter, so that it should not be incumbent on an individual or a company to take action, but a universal law restraining all such pollution, to be put in motion by the Local Government Board itself, should be adopted.

In flood times the water coming down from the Wiltshire Chalk was harder than in the summer, when they got a greater proportion of peat water from the New Forest. The hardness varied from 12 to 7 degrees. The water and areas of collection were therefore changeable. All deep well, as also river water was liable to become contaminated, and what was needed (as in their case) was a reliable system of treatment.

Attention should be directed more to the purification of water than to the question of whether a deep well supply or a surface supply yielded the better water. From whatever source obtained, water should be looked upon as liable to contamination, and a system of treatment adopted so that they might not be caught napping, as at Maidstone.

In his opinion, large sand filters with extensive areas were unwieldy, and seldom received the attention they required. Smaller filters, capable of being easily cleansed, were preferable. That was the system his company had adopted. Half an hour after the pumping operations for the day had been completed, by the simple operation of reversing the valves an upward current of filtered water was returned through the filter beds, and the matter deposited during the day's work was returned, through drains provided for the purpose, back to the river. It was found on examination that, after a year's working, the bottom layers of the filtrant used were as clean and sweet as when first brought into use.

They had also turned their attention to the aeration of the water, and, by an ingenious system, after first being strained of the river debris, the water was delivered on to the surface of the filter beds in a fine spray, thus subjecting every particle to the atmosphere. The effect of that aeration was clearly demonstrated by improved analysis.

The use of large sand filters, requiring to be entirely removed at short intervals was, he considered, attended with considerable danger, as, unless the sand was thoroughly washed, it was probable that, on reconstructing the beds, objectionable matter deposited in the first instance in the top layer of sand might be mixed up in the lower strata in the remaking; and so the newly made bed might become a greater source of danger than in its former condition.

It seemed to him that, whilst great strides were being made in increasing the power and economy of pumping plant, and the disposal of sewage, the great question of the purification of water, which was of the most vital importance, remained in almost the same state as it was half a century ago.

The following communication from Dr. G. SIMS WOODHEAD was then read:—

The questions raised in Mr. Middleton's paper are not only of vital importance at the present juncture, but they have the additional advantage of dealing with a subject in which people generally are taking a very great interest. I shall only make two or three remarks concerning some of the points raised.

The first point to which I should like to draw attention is that, as yet, we have not sufficient evidence of the action and interaction between pathogenic and non-pathogenic germs, to justify us in drawing even general conclusions in regard to the relative danger of pollution of well water and surface water; but I think we have sufficient evidence before us to enable us to state that, wherever we can get water which originally contains a small number of micro-organisms, and these of the "water" type, we should prefer it to water containing organisms derived from the surface, i.e. from putrefying or dead material.

I agree very fully with what Mr. Middleton says concerning the cleansing effect of soil, and also with what he says as to the limitations of soil filtration and its action on sewage. There can be little doubt that biological filtration, as it is called, especially when preceded by a breaking-up of the organic matter, will in time play a most important part in the treatment of our sewage; and the nearer that we can bring this process to resemble what goes on in nature (at the same time accelerating such process), the more closely shall we approximate to a perfect method of sewage disposal. A perfect system would involve the destruction of the whole of the micro-organisms present in sewage at some point, either before or after the breaking-down process has been carried out. In the one case it would be necessary to re-introduce "useful organisms," after getting rid of those with which we wish to part company; in the other case the water into which the sewage might run would furnish the necessary active agents.

Mr. MIDDLETON, in replying to the discussion, said that the point upon which he had been most attacked was that of deep well water. His meaning had been entirely misapprehended. He had no quarrel with deep well water *per se,* nor did he believe that such water was likely to be contaminated. He had merely said that if it was contaminated, the contamination was likely to be more dangerous than that of river water. Probably he had not expressed his meaning clearly in the paper. Deep well water, as a rule, was pumped directly into the district. River water, on the other hand, was generally—and should always be—treated by subsidence and filtration. If deep well water was always filtered, it would, he believed, be preferable to river water. But some deep well water was unsuitable for water supply, and suitable deep well water could not always be obtained in sufficient quantity.

As to the question of the effect of water travelling in a horizontal or nearly horizontal direction, Dr. Thresh had said that the purifying effect in such a case was the same if the process went on in waterlogged ground as if it had taken place in dry earth; but he (Mr. Middleton) felt sure Dr. Thresh was mistaken, and that waterlogged soil had little, if any, purifying effect. He was not satisfied with the instances which Dr. Thresh had given. There was nothing to show, in either case, that water found its way from the dumb well or cesspit into the well from which the water supply was derived.

Mr. Whitaker had objected to the term "impurities" being applied to mineral matter in the water; but it was clearly shown in the paper that the term "impurities" was applied to everything that was present as an addition to pure water, or water that had been filtered and sterilised, whether the additional matter was beneficial or otherwise. As to the figures relating to Maidstone and King's Lynn, as Mr. Whitaker had said, they represented the facts up to the date at which the paper was written. Mr. Whitaker had been very hard upon the inhabitants of King's Lynn, and the statement of the surveyor of that borough appeared to show that Mr. Whitaker's strictures were justified. No doubt it was true, as Mr. Whitaker had said, that the water companies were unable to protect themselves against pollution, but he thought Mr. Whitaker was mistaken in saying that the Conservancy Board of the Thames did not deal with the whole of the watershed. By the Act of 1894 the whole of the watershed was put under the authority of the Board, except that below Teddington, where the authority of the Board only extended to the tributaries for three miles from the mouth of the tributary. The River Brent came under that category.

As to north country rivers, he also had some experience of them, and he could mention a particular case in which the river was not very much better than the sewage which was discharged into it. There were many cases of that kind in the north. In the West Riding, compensation water was, until recently, given only during the day, and not during the night, and the rivers ran dry in the night, sewage matter being stored up in the morning so that the river was offensive. Mr. Whitaker said that if the sectional scheme for dealing with sewage was carried out as suggested in the paper, the public would be walking over sewage schemes all day. But they were doing so in London already, for every street had a sewer under it. Filter beds need not be worse than the now existing sewers.

Mr. Fowler had remarked that the corporation surveyor ought to have charge of the source of the water supply. If so, the corporation ought certainly to purchase the scheme. He was glad to be supported so strongly by Mr. Blount on the subject of the soap fallacy. He (Mr. Middleton) had been accustomed to use the sandstone water which some people liked for washing, but he could not say that he ever felt so clean after using that water as he did after using hard water. He was afraid that he could not agree with Mr. Fowler that one germ of contagion might be carried for thousands of miles; but, if it were so carried, it would probably do no harm to anyone who swallowed it. As to the Brent, he had lived near it, and the smell was not nice. He could quite believe that the effluent that was poured into it might be a great deal cleaner than the river itself.

In proposing the decentralisation of sewage schemes he had suggested groups of 5000 inhabitants, because the sewage from that number could be conveniently dealt with in a small area, such as could be obtained in large towns. The system, if adopted, would have to be introduced in a tentative and gradual way. The metropolis had a cumbersome and expensive system of outfall sewers, and it would probably be nearly as expensive to pull them to pieces as to keep them going; but the sectional system might be adopted in the outer areas of large towns, the effluent being simply carried into the nearest watercourse. By that means the enlargement of the trunk sewers would be prevented. Unless that was done the trunk sewers would have to be enlarged sooner or later at great expense. That was his reason for choosing small areas. That answered Colonel Jones's objection as to the smallness of the groups. He did not agree with Colonel Jones's view that light was an important item in dealing with sewage. In fact, he believed it would be an advantage to have the sewage areas and filters covered up, as they might then be better ventilated, and the smell might be more effectually carried away. He admitted, however, that light was an important item in the cleansing and purification of a river.

It was not necessary for him to enter into the smaller questions. He was glad to think that there had been a general agreement in his views. He did not think he was what Mr. Cassal had spoken of as a rabid bacteriologist. In fact, his paper showed that he was not of opinion that bacteriology would do everything; or that a bacteriological examination alone, without chemical and microscopical analysis, was of the slightest use in testing a water supply, though it was very valuable as an additional safeguard.

Obituary.

William J. Addis was born in 1832 and died on July 25, 1894, but his death was not reported until the present year. The deceased gentleman started life in India in 1851, being engaged in opening up communications under the Civil Administrative Department. On the organisation of the Public Works Department in 1855, he was appointed Executive Engineer in one of the provinces of Mysore, where he was in charge of irrigation works, roads and buildings. After some years, he took up railway construction on the Madras Railway, on the completion of which he started an engineering business in Bombay. In 1866 he was appointed District Engineer of Tanna, and later took up in succession the posts of Engineer and Secretary to the Prome Municipality and Executive Engineer to the Bassein Municipality. His last appointment was Engineer to the Coconada Municipality; and it was in that place, whilst endeavouring to improve the sanitation of that notoriously unhealthy town, that he contracted typhoid fever, which ended fatally. He was the inventor of a field cart fitted with his patent wheels and axles, which was used in the Abyssinia Expedition. Amongst other inventions are the patent rail and sleeper, the single rail tramway, and a patent conservancy cart. He published a large accurately detailed map of Bombay, and compiled a book of tables and formulæ. In 1875 he inspected and reported on the proposed harbour for Vizagapatam. At Prome he designed and laid out the large public gardens, and his projects for drainage and conservancy and efforts to encourage technical education will always associate his name with Burmah. Mr. Addis was elected a Member of the Society in 1865.

Thomas Roberts, who died on August 25, 1896 (but the particulars of whose life came to hand too late for insertion in the Transactions for last year), was born in Liverpool on June 10, 1826. Early in his professional career he was engaged in the permanent way department of the Northern division of the London and North Western Railway. In 1853 he joined the Army Works Corps under Sir Joseph Paxton, and served during the Crimean War. In 1859 he was appointed Engineer over the works of the Scinde and Punjaub Railway, being stationed at Lahore. He returned to England in 1862, and settled at Ludlow, Shropshire, where he carried on the business of quarry proprietor and colliery owner, and of which town he was a magistrate and four times mayor. Mr. Roberts was elected an Associate of the Society in 1867, and was transferred to the class of Members in 1879.

FRANK MEAD, who died on April 4, 1897, was born at Peckham, Surrey, on October 28, 1852. He was educated first at Dulwich College, and subsequently at a private school at Reigate. Being of delicate health as a youth, he was unequal to participation in sports and games, and this probably led to the development of his mental faculties. He was a gifted mathematician and scientist, there being few subjects which he did not master. His health did not permit him to enter upon business until about 1872, when he commenced work under his father at the Sutton Gas Works. He subsequently assisted his father in management of the Bournemouth Gas and Water Company. He was well acquainted with gas law, and materially assisted in obtaining the last Bournemouth Gas Act. Mr. Mead was a director of the Bournemouth Gas and Water Company; chairman of the Colombo (Ceylon) Gas Company; a director of the Hong Kong Gas Company; acting engineer to the Reigate Gas Company; secretary and manager of the Newhaven Gas Company; and consulting engineer to the Leatherhead Gas Company and other similar undertakings. Mr. Mead was elected a Member of the Society in 1886.

EDWARD ELLIS, whose death occurred on April 4, 1897, at the age of 69, was the senior partner in the firm of Edward Ellis & Son, Land Agents and Surveyors, of Exeter. The deceased gentleman had carried on the business of a land agent and surveyor for upwards of forty years. He was also well known as an engineer, and carried out drainage and water supply schemes for many of the large towns in the West of England. He was formerly surveyor to the St. Thomas Local Board, also the Dawlish Local Board, and at the time of his death he had just completed the drainage of Bude, in Cornwall. Mr. Ellis unfortunately met with a serious carriage accident some six months ago, whilst returning from an arbitration case at Exminster, and this doubtless accelerated his death. The deceased gentleman was a Fellow of the Surveyors' Institute, and was elected a Member of the Society in 1870.

ALFRED BURTON KINSEY, whose death occurred on April 19, 1897, from accidental drowning, was born on June 15. 1866. He was the son of Mr. W. Barns Kinsey, a Member of this Society, and was educated at Whitgift School, Croydon, and afterwards at King's College, London. He commenced his professional career with Messrs. Maudslay, Son & Field, and on leaving that firm in 1888 he proceeded to Natal, where he entered the office of the Harbour Works Department at Durban and was engaged there at the time of his death, Mr. Kinsey lost his life in the vain attempt to rescue from drowning a young lady who accidentally fell into a deep pool in the Umgeni river, Howick, Durban. Mr. Kinsey was elected an Associate of the Society in 1890.

JOHN HASWELL, who died on the 8th of June, 1897, in Vienna, was born in 1812 at Lancefield, near Glasgow. After attending the Andersonian University in that city, he entered the works of William Fairbairn & Co., by whom he was sent to Vienna to erect some steam engines in connection with one of the first railways made in Austria. After the completion of the work he remained in Vienna, and in 1837 laid down the plant and machinery for the locomotive and repairing shops of the then Vienna Gloggnitzer Railway. He subsequently established engineering works, in which were made some of the first locomotives turned out on the Continent. Mr. Haswell started the first iron foundry in Vienna, and was the inventor of several mechanical contrivances, notably the hydraulic forging press. Mr. Haswell was elected a Member of the Society in 1879.

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